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MONARCH

METAL WEATHER STRIPS

INTERLOCKING TYPE

STANDARD CONTROL OF AIR INFILTRATION

Architectural and Engineering Data
for
The Installation of Metal Weather Strips
on
Windows and Doors

MONARCH METAL PRODUCTS COMPANY

ST. LOUIS, MO.

AUG 24 '25

MONARCH METAL WEATHER STRIP

MANUAL

FOR

Architects, Heating Engineers and Building Contractors

A. I. A. CLASSIFICATION No. 19e14

MONARCH METAL PRODUCTS COMPANY
5020 PENROSE STREET
ST. LOUIS, MO.

PREFACE

The purpose of the tests herein described (see Pages 5-17) was to develop a standard method for testing infiltration of air around openings in buildings and thereby make it possible for the architect to definitely specify the efficiency of the weather strips that are to be installed. Since every effort was made to reproduce average conditions in ordinary practice, the specified efficiency will closely approximate the actual efficiency and furnish a basis for accurately figuring the radiation required to maintain a given temperature.

The technical discussion of air infiltration and detailed description of tests previously referred to were written by Mr. C. C. Schrader of the United States Bureau of Mines and Mr. F. C. Houghten, Research Head of the Laboratory of the American Society of Heating and Ventilating Engineers.

Weather strips of different types vary in efficiency and by varying the requirements for efficiency, the installation of various types of strips may be permitted, the infiltration known and the radiation correspondingly figured.

The apparatus for testing air infiltration was designed by the American Society of Heating and Ventilating Engineers. The sash and frames were furnished from stock by the Curtis Lumber Company. They were inspected and installed under the supervision of a representative of the Structural Service Committee of the American Institute of Architects.

This Manual, therefore, gives in detail the results of the latest and most authoritative tests on air infiltration around sash and frames, as well as detailed description of the various types of Monarch Strips and their efficiency. (See Pages 36-43).

The material is so arranged that it is readily available for reference purposes.

Comparisons of radiation figured by various methods to show the reason why a heating plant would not prove satisfactory are shown on Pages 30-33.

The design of a successful heating plant from the standpoint of operation, low installation costs and economy of fuel, must be based on using heat loss factors that will remain practically constant for years after a building has been in use.

No pre-determined number of air changes can possibly remain constant. Wind velocity and direction, size of crack and clearance between sash and frame, the number of windows in a room and the size of the room, all affect the number of air changes. The size of the room and the number of windows are the only factors that remain constant. Therefore, to use any given number of air changes is at best only guess work.

Cracks and clearances between sash and frame must remain constant if a known leakage is to be figured. Both Houghten and Schrader in their reports prove conclusively that the efficiency of the tongue and groove (rib type) weather strip, is dependent on the tightness of the frame and sash; and that the infiltration variation is the same in the non-stripped window as in the rib stripped window.

By comparison, Monarch Interlocking Tubular Equipment maintains a fixed clearance that never varies and through which a maximum reduction of infiltration is maintained, at the same time it adjusts itself to any variation in the crack. Therefore, if Monarch Equipment No. 400 is used and radiation is based on the worst condition of the sash, less radiation will be required, and consequently less fuel, than if based on the best conditions of the tongue and groove (rib) type strip.

We invite all who are interested in the contents of this Manual and desire further information, to write us and also to make use of our Laboratory and Engineering Department.

ALFRED M. LANE, President
MONARCH METAL PRODUCTS CO.

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This Manual supersedes all previous issues

A. I. A. Classification File No. 19E14

MONARCH METAL PRODUCTS COMPANY

5020 Penrose Street

ST. LOUIS, MO.

MEMBER PRODUCERS RESEARCH COUNCIL
AFFILIATED WITH THE AMERICAN INSTITUTE, ARCHITECTS

1924

MONARCH METAL WEATHER STRIPS

EQUIPMENT — Double hung windows, Casement Windows and Doors are equipped with Tested Monarch Equipment to prevent the in-leakage of air, dust, soot and rain.

MANUFACTURE — A Monarch strip is first designed and then the design and making of the machine occurs. This places all the responsibility of manufacture with the Company.

The necessary close relationship between the Designers and Toolmakers has made possible an unusual amount of accuracy and satisfaction in production.

SHIPPING — St. Louis is the geographical center of the United States and, on 29 trunk lines, offers direct shipments to almost two-thirds of the United States. A Monarch shipment from St. Louis saves time.

DISTRIBUTION — There are licensees located in all principal cities of the country, each having his staff of salesmen. These licensees are not merely representatives, as they believe in the company to the extent of being financially involved in the establishment and maintenance of their Monarch Agencies. All carry complete stocks.

SERVICE — A contract with an authorized licensee, places the responsibility entirely with the Company to deliver a practical and successful job.

All representatives have been schooled in the manufacture, installation and use of all makes of weather strips. They are especially trained to converse with, and advise architects, as to the means of obtaining the best results from the most suitable equipments.

INSTALLATION — The greatest of care is exercised in the selection of men to be Monarch mechanics. They must be experienced carpenters who are particularly skilled in the fitting and hanging of windows and doors.

Every mechanic is trained under an instructor in the installation of Monarch Metal Weather Strips before he is permitted to do work on his own responsibility. In order to make doubly sure of standard workmanship, every mechanic carries an illustrated manual to which he can always refer.

A FEW SPECIFIC INSTRUCTIONS TO MECHANICS:

"When work is being done in occupied or practically completed building —

Wear felt slippers.

Spread tarpaulins on the floors.

Use windows cloths on the sills.

Clean up all shavings and dirt in each room before leaving."

All special tools such as grooving, rabbetting planes, etc., are made in the factory. This equips the mechanic with the same kind of tools as are used in the model department.

ENGINEERING AND RESEARCH — An engineering department is maintained for the purpose of investigating air control, heating and ventilating. Architects are invited to make use of this department when preparing plans and specifications, where the above conditions are of prime importance.

e. g. It can be ascertained; the volume of air that will enter a building through the cracks around a window or door of a given size, at any wind velocity, and the amount of radiation at a fixed temperature, necessary to raise the temperature of the infiltration to the temperature required.

Recommendations and suggestions covering special and unusual conditions will be cheerfully given upon request. The Engineering Department also does a great deal of research work in conjunction with several technical institutions and has equipment necessary to ascertain the efficiency of various shapes and designs of Metal Weather Strip. Experiments are being made continuously to bring the standard of the product up to the highest degree. Special attention is given to the designing, detailing and construction of all kinds of windows and doors, with the view of making recommendations based on a wide experience in the use and application of Metal Weather Strips in practically every locality in the United States and Canada.

SPECIFICATIONS — Because of the wide difference in the efficiency of metal weather strips, the specifications should be so worded that the manufacturer shall furnish unbiased and authoritative data, that the weather strips covered in the proposal have been submitted to tests, and are at least 80% efficient in preventing infiltration.

COST — The first cost of Monarch Metal Weather Strips Equipments No. 400, 600 and 800 is the final cost. This is due to strict adherence to our four fundamentals: (1) MACHINE MADE FIT of co-operating members; (2) Self adjustment to varying window conditions; (3) Co-operation of treatments; (4) Careful analysis of non-rusting metals.

Monarch equipments when considered even as so many accurately rolled and durable metal strips are not expensive, but when considered as to function and utility, are, as all good things, extraordinarily low in cost over a period of years.

LITERATURE — Complete and comprehensive literature illustrating and describing the use and application of Monarch Metal Weather Strips will be gladly forwarded upon request, to architects, heating engineers and building contractors.

MONARCH METAL PRODUCTS CO.

ST. LOUIS, MO.

CERTIFIED INFILTRATION

Science and research are responsible primarily for the great progress which has been made in every branch of building construction. To lack faith in research, and to discount its findings, is to disbelieve in one's academic training. We can only learn about materials through research.

The results of this research have enabled architects and engineers to make comparisons.

When an architect or engineer signs his name to plans and specifications, he automatically certifies that the materials to be used in the buildings have been selected according to his best judgment and knowledge of those materials. It should be manifest that the manufacturers of the materials selected by the architects or engineers should also certify to their efficiency. It is upon this doctrine that the Monarch Metal Products Company has built its standards of relationship and responsibility to the architectural and engineering professions.

Monarch Metal Products Company stood all alone in its interest in an investigation of the infiltration of air through the cracks around windows and doors with and without weather strips, under the direct supervision of the best known authorities in the architectural professions; namely, the American Institute of Architects. Persistence and untiring efforts on the part of the Monarch Company resulted in such a test being made in the laboratories of the American Society of Heating and Ventilating Engineers in the Bureau of Mines Building, Pittsburgh, Penna. The reports of these tests have been published broadly, not only in architectural periodicals, but in the official organs of the two societies.

In addition to making investigation of the infiltration of air, the Monarch Company is collaborating with 20 universities for the purpose of compiling data on window conditions after they have been installed for a period of years. Arrangements are being made to actually measure over 10,000 windows in buildings located in more than one hundred different localities throughout the United States. From this data, we can say without fear of contradiction just what cracks and clearances must be accepted as representing standard window conditions upon which infiltration figures are based.

Up to this time, the principal reason for so many failures to properly heat buildings, due to inadequate radiation, can be directly traced to the method of computing heat losses, with particular reference to the so called "Air Change" factor. "Air change" is a misnomer, it has no definition or derivation; it is neither fundamental or basic; in practice or theory, it is misleading: Except in very isolated cases, the heat losses by infiltration (heretofore called Air Change) varied from a minimum of 50% to as high as 90% of the total of all heat losses; yet the exact amount of infiltration under various conditions has not been known.

The American Society of Heating and Ventilating Engineers and the American Institute of Architects now certify that the amount of air which is infiltrated through windows and doors without weather strips, with tongue and groove (rib) strips and with Monarch No. 400 strips, is actually known. The Monarch Company offers this information in the following pages to the architectural and engineering professions. We challenge any further tests to prove the inaccuracy of any statement made herein, provided the tests made are conducted in accordance with the code for window construction prepared by the American Institute of Architects and provided the tests are made under the same conditions as were used in the laboratory of the American Society of Heating and Ventilating Engineers.

In conclusion, when weather strips are called for in the specifications, it should be obligatory on the part of the manufacturers to certify to the efficiency of the equipment.

Reports of Cooperative Work by A. S. H.-V. E. Laboratory and the U. S. of Mines Experiment Station, Pittsburgh, Pa. Bureau

AIR LEAKAGE

THROUGH THE OPENINGS IN BUILDINGS

By F. C. Houghten* and C. C. Schrader,† Pittsburgh, Pa.

MEMBERS

Heat is lost from buildings in two ways: First, by transmission and Second, by infiltration. Both sources of heat loss are of vital concern to the heating and ventilating engineer, the architect and the owner. Both are difficult of exact measurement and determination of constants which may be used in practice with the desired engineering accuracy. As a result, the calculation of heat loss from buildings, it probably involves a greater element of chance than any other engineering problem.

Heat loss by transmission was one of the first problems to receive the attention of the Research Laboratory. Total heat loss by infiltration for a room as a unit has also received considerable attention. (Journal American Society of Heating and Ventilating Engineers, January and September, 1921). In January, 1916, a paper on "Window Leakage" by Stephen F. Voorhees and Henry C. Meyer, Jr., was presented at the Annual Meeting of this Society (Transactions, A.S.H.&V.E., 22, 1916, p. 183).

The great need for information regarding infiltration led to the present investigation of the leakage of air through and around all types of windows and doors by the Research Laboratory of the American Society of Heating and Ventilating Engineers, in cooperation with the American Institute of Architects and the U. S. Bureau of Mines. The architect is interested in the relative leakage of air through various types of windows and doors, with and without weatherstripping, in order that he may design a building with the lowest heat loss consistent with other considerations. The heating engineer needs the actual leakage through and around all types and sizes of windows and doors, or better, through a unit length of crack around such openings, in order to more accurately calculate the heat loss from any room or building and supply radiation accordingly.

This report deals with the method employed in the investigation of and results obtained for double hung windows, 2 ft. 8 in. x 5 ft. 2 in. x 1⅜ in., in a 13 in. brick wall, plastered on the inside with cement plaster. Results are given for the leakage, through such a window without weatherstripping with two types of weather stripping, around the frame, and through the brick wall itself.

Leakage of air through cracks around windows and doors, cracks in walls, and through the porous materials of which walls are made, takes place in accordance with two physical laws. First, there is an interchange of air through the wall by diffusion; Second, there may be a current of air through the wall

*Research Head, A. S. H. V. E. Laboratory.

†U. S. Bureau of Mines.

Paper presented at the Annual Meeting of the American Society of Heating and Ventilating Engineers, New York, N. Y., January, 1924.

Fig. 1. Apparatus for Testing Window Leakage

caused by a pressure difference set up by the impinging wind. The first goes on at all times, is independent of wind velocity, and is negligible. The second takes place only when there is a pressure difference between the two sides of the wall. Such a pressure difference exists whenever the wind blows against the surface of the wall or whenever the direction of the wind toward the wall is changed. For any given velocity of wind striking the wall at right angles, there is always a definite pressure produced at the surface which tends to cause leakage of air through cracks. The amount of air leakage for any crack for a given pressure difference is the same regardless of whether this pressure is produced by wind or some other cause.

Uniform air velocities over a large area for a long period of time are hard to produce and difficult to duplicate. It is much easier to produce and duplicate pressure differences on the two sides of a window by means of a blower. It was, therefore decided that for this investigation the apparatus should be so designed that a blower could be used to produce a pressure drop through the test window built in a section of wall.

Apparatus

After carefully considering all phases of the problem, the apparatus shown in Fig. 2 was designed and built under the direction of the Research Laboratory. In many respects it is similar to the apparatus used by Voorhees and Meyer in the work previously mentioned. The apparatus is built of 18 gage galvanized iron, and consists of a pressure chamber A and an air collecting chamber B separated by a section of wall including the particular window or door to be tested. Air pressure is produced in the first chamber by means of a motor driven blower, and the volume of air passing through the wall is measured by the orifice box C. The test wall, 10 ft. high x 6 ft. 6 in. wide, is built in the collecting chamber section flush with its outer edge and the pressure chamber section of the apparatus bolted on later. The desired pressure is produced in A by varying the inlet of the blower, and by means of a butterfly damper and relief slide in the connection between the blower and A. Chamber A is substantially air-tight although the requirements of the investigation do not demand that it be absolutely so. A door, 4 ft. x 1 ft. 6 in., allows entrance into this chamber to make any changes in the opening under study. The present blower has a capacity of 1100 cu. ft.

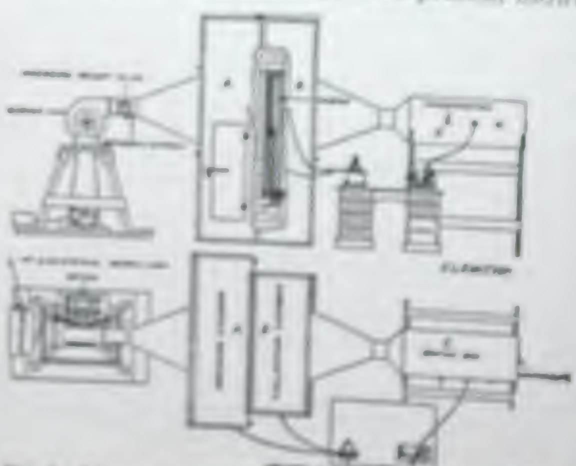


Fig. 2. Diagram of Apparatus for Testing Window Leakage

per min., at 3 in. water pressure. Chamber B must be air-tight so that all air passing through the test wall must pass through the orifice box used for measuring its volume. Every precaution including soldering

and painting the joints, was taken to make this part of the apparatus tight. Tests which will be described later in the report show that this condition was practically obtained.

The orifice box is one used by the Bureau of Mines for measuring the flow of steam and air in connection with boiler tests. The box is cylindrical in shape, 24 in. in diameter, with the orifice plates in the end. Orifice plates with openings varying from 13/32 in. to 5 in. in diameter were made so that they were easily interchangeable. These were carefully turned out in the instrument shop of the Bureau of Mines in accordance with R. J. Durley's specifications. The law of the air flow through orifices has been well established by Durley (A.S.M.E. Transactions, Vol. 27, p. 193) and others, and is given by the equation:

$$Q = 1096.5\, C\, A \sqrt{\frac{p}{w}} \qquad (1)$$

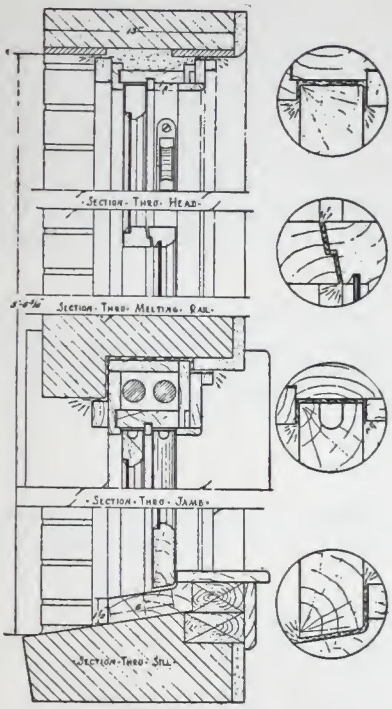


Fig. 3. Details of Window without Weatherstripping

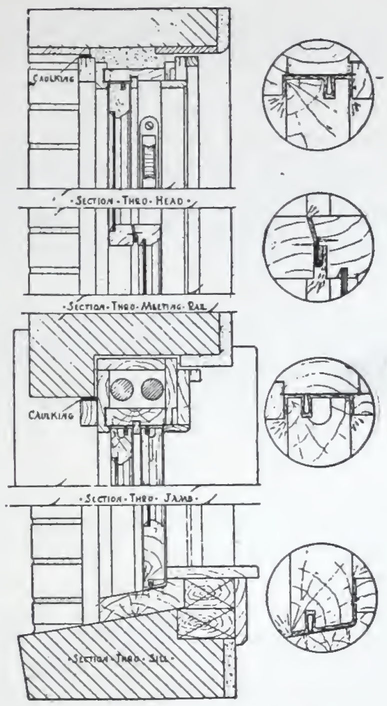


Fig. 4. Details of Window with Rib Type Weatherstripping

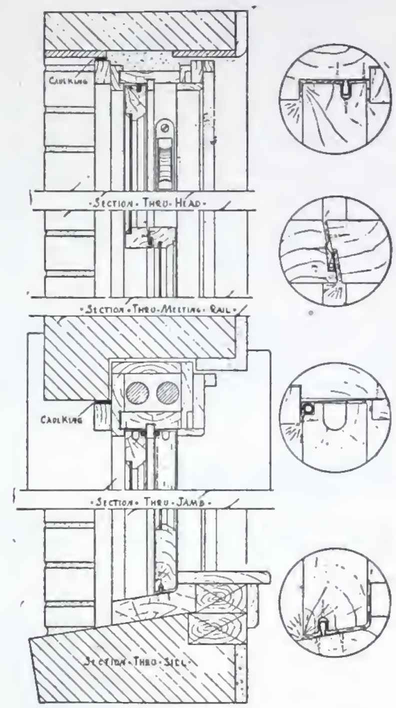


Fig. 5. Details of Window with Interlocking Type Weatherstripping

Q=quantity of air, cu. ft. per min.
A=area of orifice in sq. ft.
p=pressure head in inches of water causing flow through the orifice.
w=weight of air in pounds per cu. ft.
C=coefficient of discharge

The coefficient of discharge used is 0.6 because it approaches this value at the pressures obtained for all the orifices used.

The pressure drop through the orifice which in this case is the difference between the pressure in the orifice box and the atmosphere, was measured by a Wahlen gage accurate to 0.0001 in. of water. This gage was developed at the University of Illinois and is fully described by A. C. Willard in the University of Illinois Engineering Experiment Station Bulletin 112.

While the accuracy of the orifice method of measuring air flow is well accepted by those familiar with its use, it was thought desirable to compare it with some other method. The orifices in the box as used in the tests were compared with a dry gas meter used as a standard in the meter testing laboratory of the Equitable Gas Co., Pittsburgh. These tests showed that the results for the orifices using the equation given above were more consistent than those for the gas meter with which it was compared. As a further check of the relative readings of the various sized orifices they were compared with each other and with duplicate orifices by placing a second orifice in the window opening in the test wall in series with the box. This was done when the total leakage through the wall was reduced to a negligible but known value.

The pressure drop through the test wall was measured by an inclined U-tube gage of a particularly accurate type designed and built by the Bureau of Mines. It was compared with the Wahlen gage and found to be accurate to 0.003 in. of water. The two legs of this gage are connected by rubber tubing to chambers A and B.

A test of any particular window was made by regulating the blower pressure so as to give the desired pressure drop through the window indicated by the differential gage. The size of the orifice chosen for any test was such as to give a pressure in the orifice box of from 0.3 to 0.7 in. of water. When these conditions were maintained for a sufficient time to insure equilibrium, the two pressure gages were read simultaneously. By repeating the tests for a large number of pressure differences through the window, data was obtained for plotting a curve giving leakage through the wall in cu. ft. per min. against pressure differences in inches of water or wind velocity. All velocities and volumes given are for air weighing 0.07488 lb. per cu. ft corresponding to air having a barometric pressure of 29.92 in. of mercury, a dry bulb temperature of 68 deg. fahr. and 50 per cent relative humidity. Many tests in such a series were repeated after opening and closing the window and also after taking the sash out of the frame and replacing them.

Data and Results

The results given in this paper are for a double hung window, 2 ft. 8 in. x 5 ft. 2 in. x 1⅜ in. in a 13 in. brick wall plastered on the inside with cement plaster. The brick wall was built, the plastering was done and the window hung by mechanics in the employ of large contracting firms in the city of Pittsburgh. The work was done according to specifications supplied by and under the direction of S. F. Heckert, representing the Structural Service Committee of the American Institute of Architects. All changes in the window, such as hanging a new sash and applying weatherstripping were made also by mechanics under his direction. Every precaution was taken to make the wall and window represent work done by the ordinary contractor under the supervision of an architect. The sash and frame were given three coats of paint. Fig. 3 is a vertical section through the unweatherstripped window with a horizontal section through one side of the frame.

For convenience in presenting, the results are given in two sections. First, those obtained in a preliminary series of tests on the unweatherstripped window in the wall as built, and with certain changes such as calking the frame, sealing cracks, and painting the wall; Second, results obtained from a large number of tests with various sash hung under different conditions with and without weatherstripping.

Preliminary Tests

Preliminary tests were made in order to study the working of the apparatus itself and in order to differentiate between the various channels of leakage through the window and wall. Leakage through the

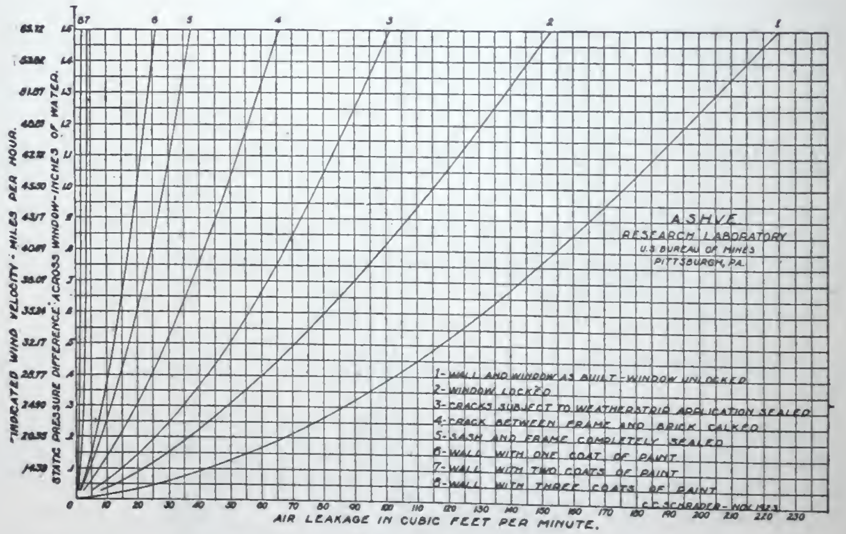


Fig. 6. Results of Tests of Leakage Through Various Parts of Window, and Wall

window may be divided into the following parts. First, that which passes through the cracks, around the sash perimeter which are subject to weatherstrip application; Second, that which passes through the cracks between the frame and the brick and can be eliminated by calking under the staff bead or brick mold. This may be called the frame leakage. Third, leakage through other cracks in the frame or sash which cannot be eliminated by either weatherstripping or calking and may be called the "elsewhere" leakage.

Before making the first series of tests, the joint between the brick and the chamber wall was calked so that all leakage would take place through the wall or window. In all other respects, the wall and window were in the condition in which they were left by the mechanics, the sash having been fitted as tight as would allow free sliding, though probably tighter than would be allowable in actual construction because of swelling in rainy or damp weather. The window was left unlocked. A large number of tests were made

with various pressure drops through the wall, many of them being duplicated several times after opening and closing the window, in order to determine the variation due to the way in which the window was closed. No care was taken to close the window in any particular way other than to see that the lower sash was pushed down against the sill and the upper sash raised until the meeting rails were even. Curve 1, Fig. 6, shows the leakage for this condition for various pressures or wind velocities. The shape of the curve is characteristic of all curves obtained with the various conditions of the window and, as would be expected, shows the same characteristics as the curve for the flow of air through an orifice. For a pressure difference of 0.1 of water through the wall corresponding to a wind velocity against the wall of 14.4 miles per hr., 42 cu. ft. of air per min. passed through the window and wall. With a pressure drop through the wall of 1 in. of water, corresponding to a 45.5 miles wind velocity, 174 cu. ft. per min. passed through.

The second series of tests was made under the same conditions as the first series excepting that the window was locked. Curve 2 shows the leakage for various wind velocities for the locked window. Locking caused a reduction in leakage of 20 cu. ft. per min. with a 14.4 mile wind and 64 cu. ft. per min. with a 45.5 mile wind. The third series of tests was made with the cracks around the sash perimeter, which are sub-

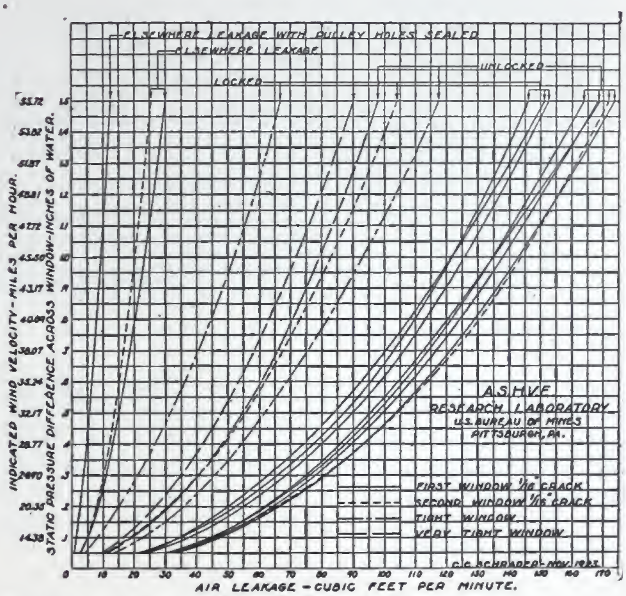


Fig. 7. Results of Tests on Windows with Various Cracks, Showing Variation in Leakage for Different Tests on Same Window

ject to weatherstrip application, sealed with a rubberized adhesive tape. This tape was tested and found to be as effective as a plastic calking compound and was more easily and quickly applied and removed. The leakage for this series of tests is given in Curve 3, and the difference between this Curve and Curve 1 or 2 indicates the maximum possible reduction in leakage by a perfect weatherstrip.

Before making the next series of tests the staff bead, or brick mold, was removed and the crack between the frame and the brick wall calked. The brick mold was then replaced. Calking was also applied between the frame and the brick. The leakage for this condition is given in Curve 4 and the difference between Curve 4 and Curve 3 gives the leakage between the frame and the wall, commonly called the frame leakage.

In order to determine the elsewhere leakage, a sheet of galvanized iron was fastened by screws over the entire frame and the edges were sealed with calking compound. The leakage for this condition is given in Curve 5. The difference between Curve 4 and Curve 5 is the leakage stopped by the galvanized iron and is the elsewhere leakage.

Curve 5 shows a considerable leakage which does not go through the window opening, but through the brick wall and the plaster. To prove that this leakage was really through the brick wall, the wall was painted one coat with asphaltum paint and another series of tests made. The results of this series is shown in Curve 6. The difference between Curves 5 and 6 represents the leakage stopped by one coat of paint. The wall was then thoroughly inspected and any visible cracks in the mortar closed with calking compound and given second and third coats of paint after each of which additional series of tests were made resulting in Curves 7 and 8, respectively. These curves show the reduction in leakage through the wall by each coat of paint. Another coat of paint was applied later and the leakage through the wall was further reduced to one half of that shown in Curve 8. The total leakage through the entire wall had been reduced by the vari-

ous processes from 4.5 cu. ft. per min. to 0.2 cu. ft. per min. for a 14.4 mile wind, and from 28 cu. ft. per min. to 0.9 cu. ft. per min. for a 45.4 mile wind. No doubt further painting would have reduced the leakage still more, but that shown by Curve 8 was so small that it was considered negligible.

With the leakage through the window and wall reduced to a minimum, some special tests were made in order to determine the magnitude of any leakage which might occur from Chamber B. The leakage through the wall and window as indicated by the orifice reading is too small by the amount of the leakage from Chamber B. While every precaution was taken to eliminate this leakage, it was not possible to do so entirely. However, as shown by the following tests, it was negligible.

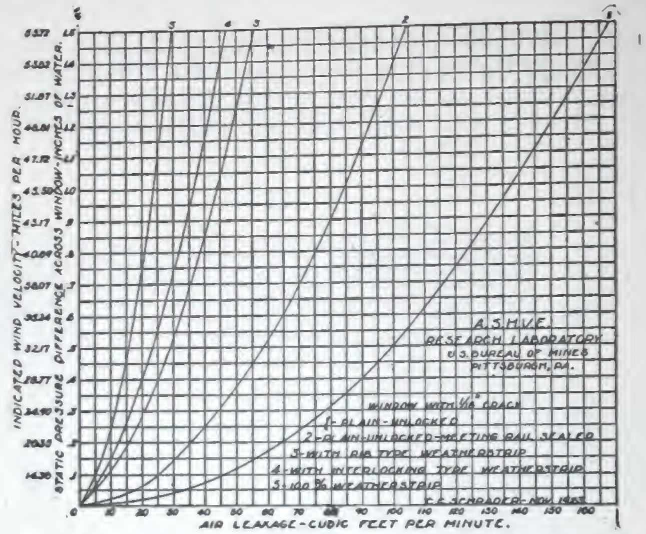


Fig. 8. Results of Tests on Window with 1/16" Crack Around Perimeter

When the leakage through the wall as shown by the orifice reading was reduced to a minimum, a pressure drop of 1.5 in. of water through the wall, gave a pressure difference of 0.066 in. between the second chamber or orifice box and the atmosphere when a ⅝ in. orifice was used. That is 1.41 cu. ft. per min. passing through the orifice and an unknown amount which we will call x was leaking from the second chamber. The leakage through the wall was then 1.41+ x cu. ft. per min. We wish to determine the value of x for all pressures. Since x cu. ft. per min. were passing through the various openings with an orifice pressure p, x is given by the orifice formula as:

$$x = 1096.5\, C\, A \sqrt{\frac{p}{w}} \qquad (2)$$

where the various symbols have the same significance but probably not the same values as given in equation (1). A and C are not known but are constant for the same conditions and w is also constant; A C and w can therefore be included with the numerical constant 1096.5 as K. Our equation then becomes,

$$x = K \sqrt{p} \qquad (3)$$

and the leakage from the second chamber for an orifice pressure of 0.066 in. becomes:

$$x = K \sqrt{.066}$$

The leakage through the wall for any pressure drop may likewise be expressed as:

$$y = K_1 \sqrt{p} \qquad (4)$$

and for a pressure drop of 1.5 in. as,

$$y = K_1 \sqrt{1.5} = 1.41 + K \sqrt{.066} \qquad (5)$$

The orifice was eliminated by using a plate without a hole and the leakage through the wall became equal to that from the second chamber. The pressure drops observed through the wall, and between the second chamber and atmosphere were 0.045 in. and 0.701 in. respectively; therefore,

$$y = K_1 \sqrt{.045} = x = K \sqrt{.701} \qquad (6)$$

Solving equations (5) and (6) simultaneously gives K=0.308 and the leakage from the second chamber for all pressures becomes,

$$Q = 0.308 \sqrt{p} \quad (7)$$

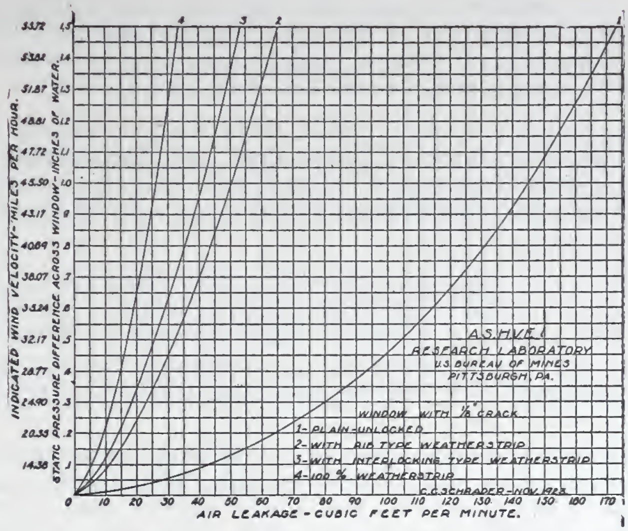


Fig. 9. Results of Tests on Window with ⅛" Crack Around Perimeter

This gives a leakage from the second chamber of 0.258 cu. ft. per min. for an orifice pressure of 0.7 in. of water, the maximum used in the tests. This leakage entirely negligible in comparison with the results obtained.

When the galvanized plate was removed and also when the tape was removed from the sash perimeter cracks, tests were made in order to check the decrease in leakage resulting from their application. The calking around the frame and the paint on the wall were not removed after having been applied, so that the curves in all figures after Fig. 6 do not include the frame and wall leakage, and show only the leakage through the window.

AIR LEAKAGE AROUND WINDOW OPENINGS

By C. C. Schrader,* Pittsburgh, Pa.

MEMBER

This report is the second one dealing with the air leakage problem being investigated at the Research Laboratory. The first report, Air Leakage through the Openings in Buildings, was published in the February, 1924 Journal and included a description of the apparatus and the method of procedure. The tests in both experiments followed the same general routine, and in each case the same frame was used with the same kind of sash, namely, double hung wooden sash, 2 ft. 8 in. by 5 ft. 2 in. by 1⅜ in.

The principal facts brought out in the first report were that increasing the crack around the perimeter of a plain sash did not materially increase the leakage, and that weather-stripped sash while permitting much less leakage, showed a small increase in leakage with increase in crack. These facts were established by making several hundred tests. The present report deals with effect of increasing the width of the stile, that is, increasing the clearance.

Fig. 1 illustrates what is meant by crack and clearance. The crack around the sash perimeter is equal to one-half the difference between the width of the frame and the width of the sash, that is, the crack is the same on each side of the sash. The clearance is the difference between the width of the stile and the thickness of the sash. These terms are chosen arbitrarily to distinguish the two principal air passages which are found in double hung windows, and they will be used frequently throughout the report and should not be confused.

In fitting the sash for these tests it was discovered that they were thicker than those used in the first tests, which led to an investigation as to the actual thickness of the sash in each case. All of the sashes were measured with calipers, and it was found that those used for the tests in the first report were 1-21/64 in. thick while those used in the new tests were 1⅜ in. thick. The stile previously measured was 1-7/16 in. in width. In view of this information a statement made in the first report must be corrected, which was that the difference between the width of the stile and the thickness of the sash was 1/16 in. when it was actually 7/64 in. This difference in clearance is probably due to manufacturing practices, as some mills use the specified dimension for the thickness of the sash while others use it for the width of the stile.

In order to test the effect of different clearances it was necessary to have stops that could be moved to any desired distance from the parting bead. Therefore the stops were removed and slots cut in them so that they could be screwed to the frame to give a maximum of ¼ in. clearance. Known clearances were obtained by strips of cold rolled steel of convenient thicknesses, and these strips were measured with a micrometer to determine their exact dimensions. A strip of a thickness equal to the desired clearance was

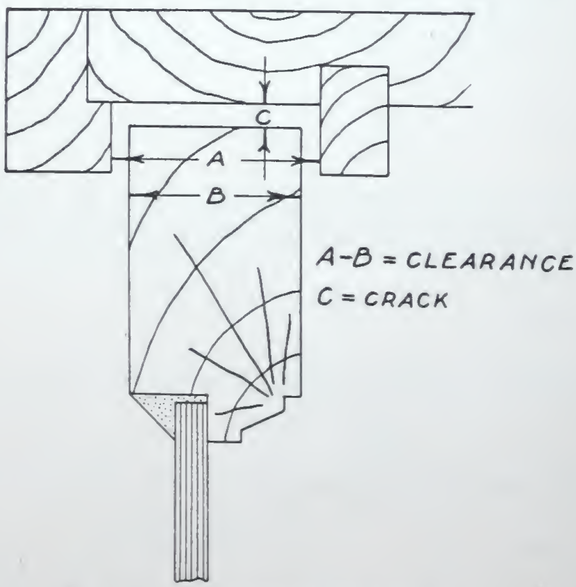


Fig. 1. Diagram Illustrating Crack and Clearance

inserted between the sash and the stop, the whole pressed firmly against the parting bead, and the stop screwed on in position. The strip was then removed, and in this manner any desired clearance was obtained. When weather stripping was used it held the sash against the parting bead, so that the clearances could be obtained in the same manner. The cracks around the stop were sealed to prevent leakage through them.

*Research Engineer, A. S. H. & V. E. Laboratory.

For presentation at the Semi-Annual meeting of the American Society of Heating and Ventilating Engineers, Kansas City, Mo., June, 1924.

Procedure

Four sets of sash were fitted with cracks of 1/16, ⅛, 3/16, and ¼ in. Each set was tested with clearances varying from 1/32 to ¼ in. Each test was repeated a number of times because no two tests gave exactly the same leakage, and it was necessary to obtain average results. Before duplicating any test the window was opened and closed, and the stops were removed and then returned to as nearly the same position as possible. The weatherstripped sashes were tested in the same way.

Plain Window

Fig. 2 gives the results of tests of a plain window with various clearances. The tests proved that the size of the crack around the perimeter of the sash has no appreciable effect on the leakage. Therefore the results apply to any window of the type tested with a crack of from 1/16 to ¼ in. In practice most new sashes are fitted with the crack at least 1/16 in., and this crack becomes greater as the sash dries out and shrinks. It should be clearly understood that each curve is the average obtained from a number of tests, and the results of any one test may vary from the given curve by four or five per cent. The figure shows that the leakage increases rapidly with increase in clearance.

Fig. 3 is obtained from curve 4 in Fig. 2 and is drawn to show the relation of leakage to wind velocity. The graph thus drawn shows a slight double curve, but it is seen that it varies but little from a straight line. In some cases the double curve is more pronounced but the curve does not reverse until the velocity has reached twenty-five or thirty miles per hour. Hence no greater error is introduced by taking any point on the leakage curve below thirty miles per hour, to determine the leakage per mile of wind velocity.

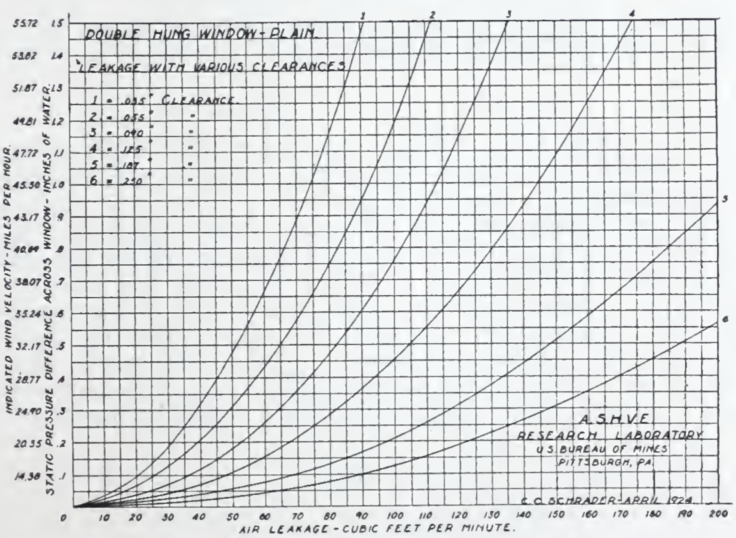


Fig. 2. Leakage Through Plain Window with Various Clearances

Since the velocity used in most calculations of window leakage is about fifteen miles per hour, or approximately 1/10 in. water pressure, values at these points were taken from the curves in Fig. 2 and plotted against clearance. Fig. 4 was thus obtained. It is seen that a straight line passes close to all these points, and that the variation from the points plotted will be within the limits of the above variation of the original tests. The line drawn does not pass through zero leakage for zero clearance, and therefore the leakage will not vary in direct proportion to the clearance, which is to be expected because the surfaces of the window are not perfectly true, and regardless of how closely they are held together some leakage will always occur. If the sashes were not free to move with the pressure of the wind and were always held in the middle of the stile, a direct ratio of leakage to clearance would be expected. However the movement of the sash introduces a variable element, and it is difficult to determine its effect. It must be remembered also that the leakage at zero clearance is not the elsewhere leakage. The conditions for determining the elsewhere leakage require that certain openings around the sash be sealed so that no leakage will take place through them, whereas regardless of how tightly the sash fits between the stops some leakage will occur through these openings due to the uneven surfaces caused by warping and so forth. (For determination of elsewhere leakage refer to first report mentioned above). It is probable that the elsewhere leakage, particularly through the pulley holes, increases as the clearance is made greater, but the increase is too small to be differentiated from the variation that may take place in two sets of the same condition.

From the standpoint of the heating engineer the most convenient terms expressing infiltration are cubic feet per hour, per foot of crack, or per mile of wind velocity. Using these terms the infiltration for

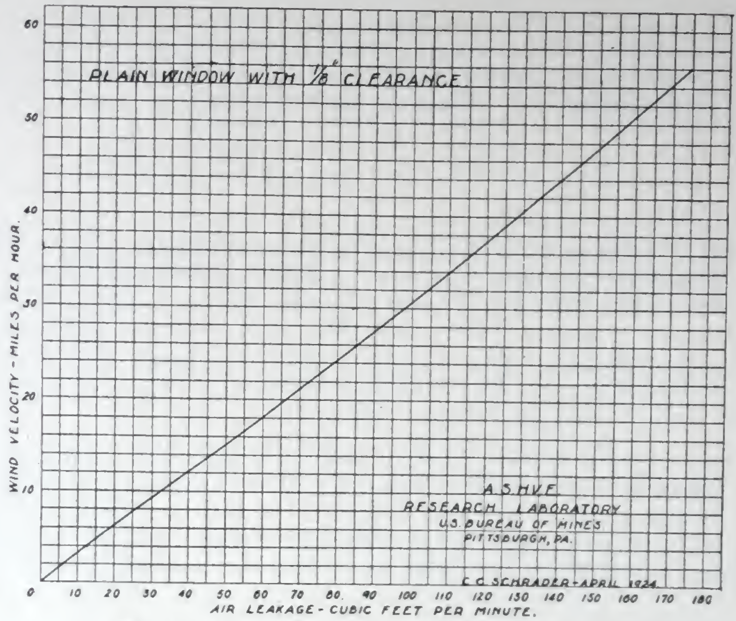


Fig. 3. Relation of Leakage to Wind Velocity

any room can be easily computed by multiplying by a constant depending on the wind velocity and the number of feet of crack. Fig. 5 was obtained by expressing the values in Fig. 4 in these terms.

Weatherstripped Windows

In the first report it was shown that the leakage through a weatherstripped window increased as the crack was made larger. Fig. 6 shows what happens when the crack is kept constant and the clearance increased in a window with the interlocking type strip applied. The increase in leakage with increase in clearance is probably due to greater leakage through the pulley holes which is caused by decreased resistance in the path of the air to the pulley holes. This evidence supports further the statement previously made that the elsewhere leakage increases slightly as the clearance decreases. In fact, it is the only explanation that can be found for the increase in leakage since the sash is held against the parting bead in the same position by the weatherstripping, all other openings around the sash remaining the same. The increase in leakage is quite pronounced until the clearance becomes equal to the crack, after which the increase is not so rapid. Fig. 7 illustrating this point shows the leakage through windows with the interlocking type weatherstrip for all the cracks and clearances tested. Fig 8 gives similar data for windows fitted with rib

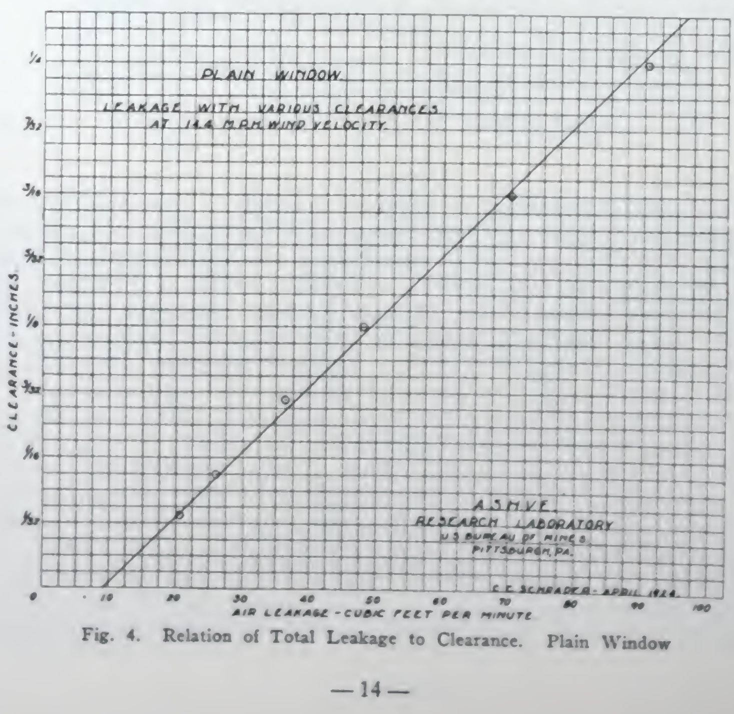


Fig. 4. Relation of Total Leakage to Clearance. Plain Window

type weatherstrip. A comparison of the two figures brings out the greater consistency in results obtained with the interlocking type of strip, which is to be expected, as this type of weatherstrip holds the sash in the same position at all times. With the rib strip the sashes are free to move from side to side a distance depending on the size of the crack, and since it is impossible to return them to exactly the same position after each test the results become more varied.' This change of position of the sash often causes the leakage with a small clearance to be greater than that with a larger clearance, for a slight change is sufficient to affect the difference. This fact is particularly true when the crack is large and permits considerable divergence from the previous position of the sash.

It is not the purpose of this report to draw a comparison between the relative values of different types of weatherstripping. However some explanation is necessary to understand thoroughly the conditions under which these tests were conducted so that comparison may be made with other data on the subject. Concerning the interlocking type of weatherstrip all that needs to be mentioned is that it has metal members on both the sash and the frame, and they are so constructed that one fits into the other. The rib type strip

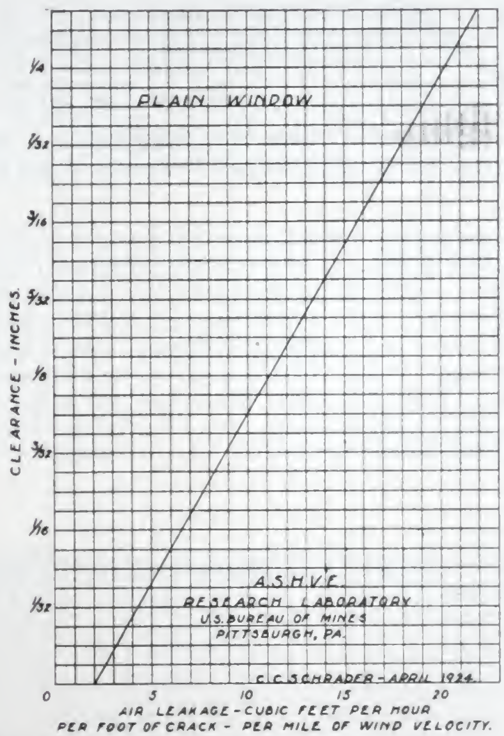


Fig. 5. Relation of Leakage per Foot to Clearance. Plain Window

has one metal member fastened on the frame which fits into a groove ploughed in the sash by the carpenter applying the strip. The width of this groove in comparison with the width of the metal member may be the determining factor in the leakage through a window to which this type of strip is applied. In this instance the rib was 1/8 in. wide and the groove 1/32 in. wider. De Volson Wood (A.S.M.E. Transactions, Vol. 10) gives the lateral expansion of white pine as 2.6 per cent from dryness to saturation. With the groove 5/32 in. wide a variation of 0.004 in. in width is given from one extreme to the other. Though most sashes at the present time are made of some less expensive wood, such as cypress or spruce, it is probable that the expansion of either would not be much greater than white pine. Therefore the clearance allowed here would be ample in any case.

No tables of leakage are included in this report because any values desired can easily be found from the curves. Another reason is that the most important factor in the problem of infiltration has been the subject

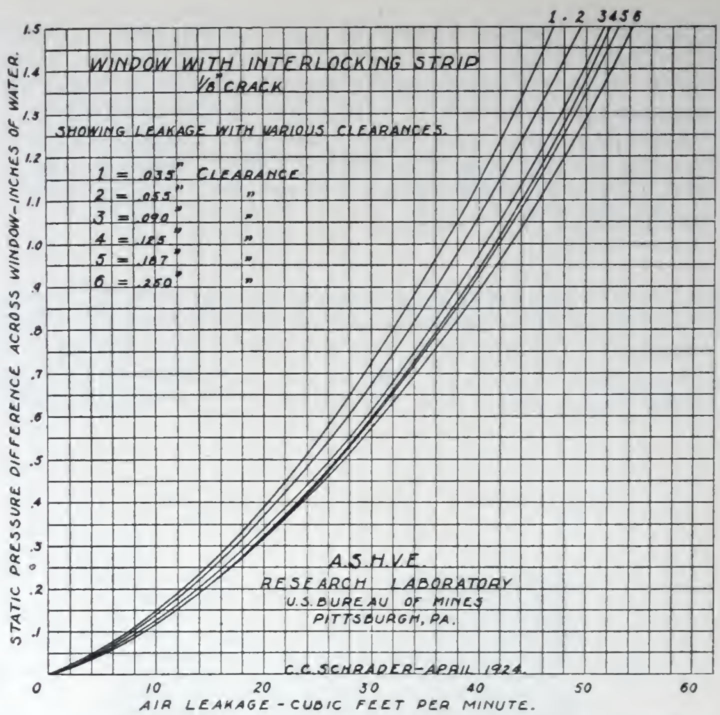


Fig. 6. Leakage Through Weatherstripped Window with Various Clearances.

of much discussion and is not yet definitely determined. This factor is the clearance of the average window after it has been in service a sufficient length of time to have reached its final condition in regard to shrinkage which is a question for architects and heating engineers to decide. A simple solution to the problem can be obtained by actually measuring and then averaging the clearances of a sufficient number of windows in buildings which are at least five years old. Different results would probably be obtained for sashes of different thicknesses because, although most windows leave the mill with the same clearance, those made of heavier wood will shrink more. Data obtained from twenty large manufacturers of windows have shown that almost all sashes from 1⅜ to 2½ in. thick are allowed 1/16 in. clearance. It remains to be decided what the final clearance will be when the sashes have thoroughly weathered and dried.

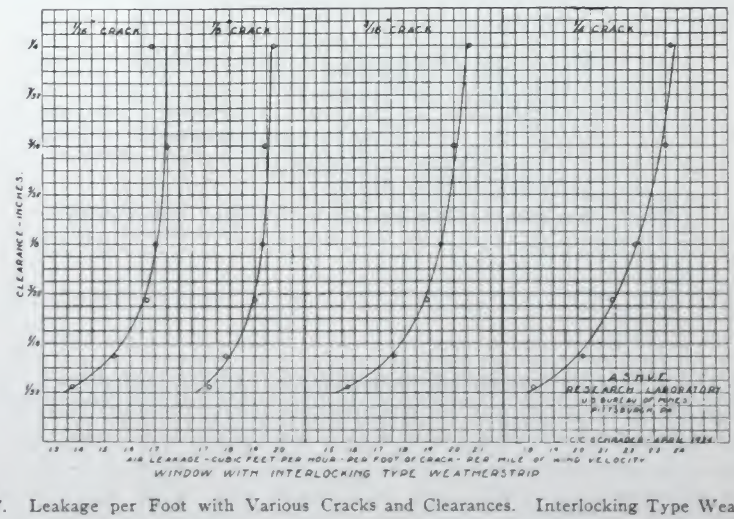


Fig. 7. Leakage per Foot with Various Cracks and Clearances. Interlocking Type Weatherstrip

The importance of the increase in clearance is shown by the following example: The capacity of a room 14x12x10 ft. is 1680 cu. ft. With two windows such as those tested there would be 36.67 ft. of crack. From Fig. 5 the leakage for 1/16 in. clearance is 6.6 c.f.m. per ft. of crack per mile of wind velocity. Assuming a 15 mile wind, the infiltration would be 6.6x36.67x15 or 3630 cu. ft. per hr., or $\frac{3630}{1680}=2.16$ air

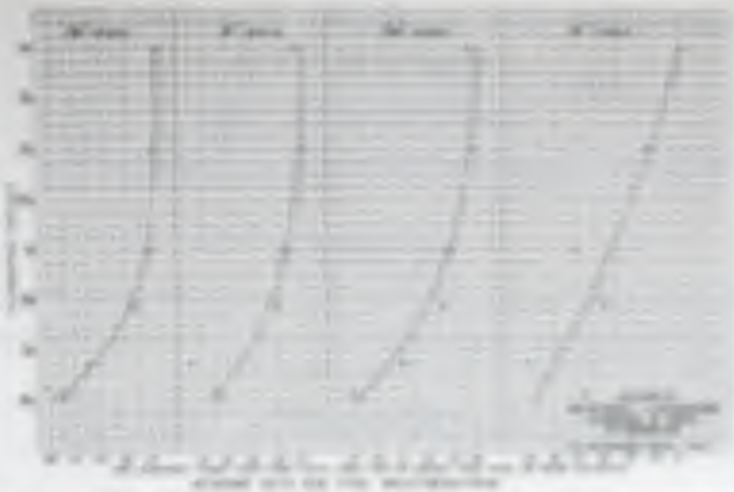


Fig. 8. Leakage per Foot with Various Sashes and Clearances. Rib Type Weatherstrip

changes per hr. If the clearance increases to 1/8 in. the leakage increases to 11.2 cu. ft. per hr. per ft. of crack per mile of wind velocity. The infiltration would then be [illegible] or [illegible] cu. ft. per hr., and the number of air changes would be increased to 3.66 per hr.

It must be remembered that in all these tests the crack between the frame and the setting was sealed, and this practice being easily done has become more and more common, and it has prevented considerable leakage, and thereby effected a saving in radiation surface and fuel.

CODE FOR TESTING METAL WEATHER STRIPS

Prepared by A. I. A.

CONDITIONS OF TEST

1. Tests shall be confined to windows and doors of wood construction.

EQUIPMENT

2. All windows and doors shall be of a common standard construction in general mill practice.

3. Double hung windows shall be of standard size 3x6′ box frame with pendulum in box, standard pulleys for sash cord, sashes 1⅜″ thick, back puttied and glazed.

4. Casement shall have double sash swinging in with rabbetted plank frame, sash 1⅜″ thick with rabbetted meeting rail and rabbetted bottom rails, with corresponding rabbet on sill. Casement opening 36″x48″. All rabbets to be ½″ in depth.

5. Doors shall be standard 3x7″. 1¾″ thick, rabbetted plank frame, rabbet ½″ in depth with standard oak threshold or carpet strip.

HARDWARE

6. All openings to be equipped with standard regular hardware.

7. Double hung windows to have fitch pattern sash lock, two bar lifts.

8. Casement window 3½x3½″ loose pin butts, two to each leak, standard burn buckles on center of sash and barrel or box bolt on face of sash at sill.

9. Doors—4½x4½ loose pin butts, standard cylinder lock with three hole keeper.

CRACKS

10. Double hung window cracks will be accepted as standard with a minimum of 1/16″ and a maximum of ¼″on each side between sash and pulley stile of frame; clearance between the sash and the guide members (inside stops, parting bead and blind stops) shall be accepted as standard with a minimum clearance of 1/32″ on each side of sash and a maximum of 3/32″ on each side of the sash. The cracks between frame and sash at head and sill shall be a minimum of ⅛″ and a maximum of ¼″.

11. Casements—minimum on hinge side ⅛″, maximum ¼″, Meeting rail, head and sill minimum 1/16″, maximum ⅜″.

12. Doors—Minimum crack on hinge side ⅛″, maximum ¼″. Same at head. Lock side minimum ⅛″ at outside corner, maximum ⅜″. Sill maximum ¼″. (Minimum cracks on the hinge side of all hinge openings is established to prevent hinge binding).

LUMBER

13. All frames, sashes or doors shall be made of

a—White Pine
b—Spruce
c—Fir
d—Cypress
Equal to No. 1 grade.

PAINTING

14. All woodwork shall be given three coats of lead and oil.

FITTING AND HANGING

15. All windows and doors shall be hung according to the usual practice of the trade, employing average skilled labor.

TESTS

16. All openings shall be tested.

a. With minimum cracks as specified (Window unlocked, lower rail of bottom sash down on sill meeting rails even).

b. Apply metal weather strips, resume test.

c. Where two member weather strip equipment is used, remove the member attached to the sashes or door, increase the size of crack to 50% maximum.

d. Test.

e. Re-attach weather strip member to sash only.

f. Test.

g. Repeat for maximum crack.

(No strip member is to be removed from a frame once it is attached).

OPERATION

17. Note the degree of manual effort necessary to open and close the openings (slight—medium—hard) at the end of each test, with weather strips applied.

18. Note the manual effort and skill necessary to remove sashes or doors from the frames (easy—average—hard) with weather strips applied.

ELSEWHERE LEAKAGE

19. Heremetically seal all cracks that are subject to weather strip application with putty or other suitable compound. Record leakage. Define as 100% efficient window. Remove sealing material and proceed with test.

RATING

20. All weather strip equipment shall be rated to their percentage of efficiency to the 100% window. Note leakage through crack aperture of average width at wind velocity equal to five, ten, fifteen, twenty and twenty-five miles per hour.

DIRECTION AND WIND

21. Direction and wind shall be 90° and 45° and parallel to the plane of opening.

DESCRIPTION

22. All openings, frames and weather strip equipment used shall be described by dimensioned drawings. Weather strip material shall be described by the kind of metal and gage.

WATER LEAKAGE

23. Casement windows and doors shall be tested for water leakage.

METHOD OF TEST

24. A spray of water the full width of the frame 6″ above the head of frame and 12″ to the windward side of frame against which wind shall be blown at the velocity called for in air leakage.

MANUFACTURERS' SPECIFICATIONS

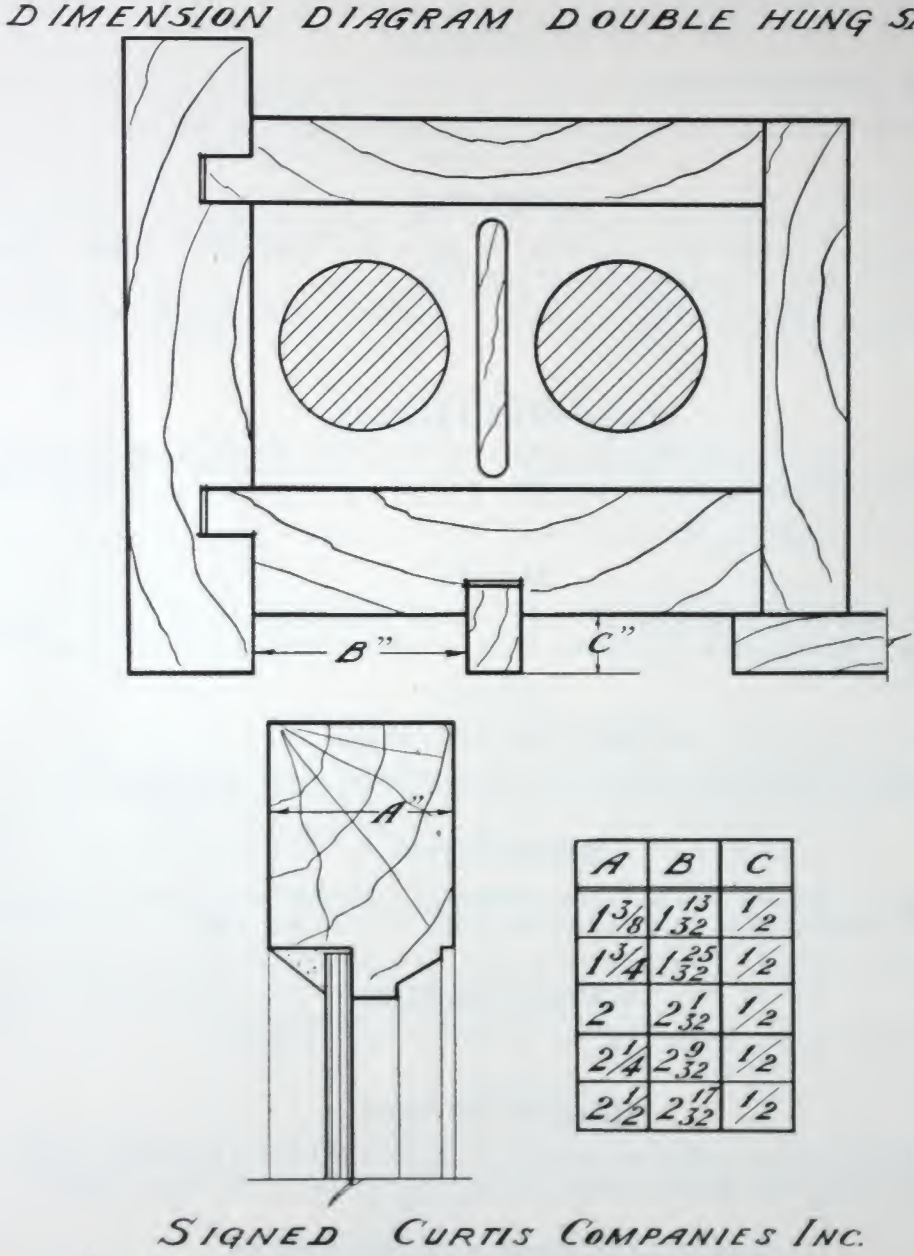
25. Manufacturers shall furnish the number, name or catalog description of each kind of equipment used together with where it is to be applied, to the sash or frame and each kind of weather strip to be tested. Samples to be furnished properly labeled with the description attached, filed with whoever is to make the test.

CERTIFICATION

26. A standard form of certification as approved by the Structural Service Committee of the A. I. A. and the Bureau of Research of the Heating and Ventilating Engineers, shall be used by parties making the test in reporting the results of such test. Certified copies of report shall be filed with the Structural Service Committee of the A. I. A. and Bureau of Research of the Heating and Ventilating Engineers.

REPORT FROM CURTIS CO., INC.

Duplicate drawings as shown below were submitted to twenty leading planing mills and dimensions filled in by them represent an average clearance. B-A to be a minimum of 1/16″ when sash and frames are delivered to the building.



A	B	C
$1\frac{3}{8}$	$1\frac{13}{32}$	$\frac{1}{2}$
$1\frac{3}{4}$	$1\frac{25}{32}$	$\frac{1}{2}$
2	$2\frac{1}{32}$	$\frac{1}{2}$
$2\frac{1}{4}$	$2\frac{9}{32}$	$\frac{1}{2}$
$2\frac{1}{2}$	$2\frac{17}{32}$	$\frac{1}{2}$

Fig. 12.

It is quite essential before attempting the use of infiltration figures, to know the size of the clearance (B-A on the drawing shown on this page). To ascertain this starting point, the sheet shown here was mailed to twenty of the largest and most representative mills manufacturing frames and sash. These mills were asked to show the clearance allowed by them in shipping to a job. Of the replies received, the majority gave the dimension B-A as 1/16″; and it is this 1/16″ that all shrinkage starts from, as the sash and frame are installed with this clearance. This clearance applies for all thicknesses of sash, namely 1⅜″, 1¾″, 2″ and above. The drawing is an exact reproduction of the report received from Curtis Companies, Inc.

(SPECIFICATIONS)

MILL WORK

1. **Note**—General conditions and materials are a part of the specifications for this branch of the work.

2. **Extent of Work**—The work under this heading shall include the furnishing of all material and labor to construct in a substantial, neat and workmanlike manner, all finished mill work shown on the drawings and finished woodwork other than that specified under Carpentry.

3. **Material and Workmanship**—The materials used in this work must be of the best quality called for, free of defects. The lumber in all cases must be well seasoned, kiln dried, well put together, mortised and tenoned, joints glued and made in section as large as practicable.

All woodwork for the exterior such as frames, sash and work exposed to the elements of weather, shall be good sound close grained, clear spruce or California Sugar Pine and must be free from saps, knots, or other imperfections that may tend to impair its strength or durability. Put outside work together with stiff white lead and in a manner to exclude water from the joint. Apply the lead just before the joints are made and do not allow the lead to become dry. The interior finished woodwork in general to the various parts to be of kind and quality shown on drawing or herein called for.

All woodwork stained for finish must be selected clear and all woodwork for painting and enameling must be reasonably clear.

4. **Double Hung Box Window Frames**—Box Window frames shall be constructed with 1⅛″ Yellow Pine pulley stiles, 1⅛″ Yellow Pine head, ⅞″ inside casing and back lining, 1⅛″ outside casing extending 1″ beyond back of frame to form wind break; 1¾″x1¾″ hanging stiles; pulley stiles to be dadoed into sill and head, and tongued into outside casing and inside casing; 1¾″ weathered sub sill; parting stops to be ½x⅞″ Yellow Pine; hanging stiles, outside casing and sill to be Cypress or Spruce; inside casing and back lining to be sound merchantable Yellow Pine; pulley stiles to be tapped for 2½″ diameter axle pulleys and to have pockets prepared for the reception of weights.

Also, provide metal pendulum strips of 20 gage galvanized iron between weights.

5. **Plank Window Frames**—Plank window frames to be manufactured of 1¾″ Spruce or Cypress, with 1¾″ weathered sub sill and 1¾″ exterior hanging stiles. Rabbets for sash to be ½″ deep and 3/16″ wider than thickness of sash.

Inside edge of jambs, head and sill to be plowed to receive jamb linings and stool.

Provide 1¾″x1¾″ wind break of sound merchantable lumber, plowed ½″ into back of jambs and head.

The meeting rails to have astragals and the backs moulded for a water tight joint.

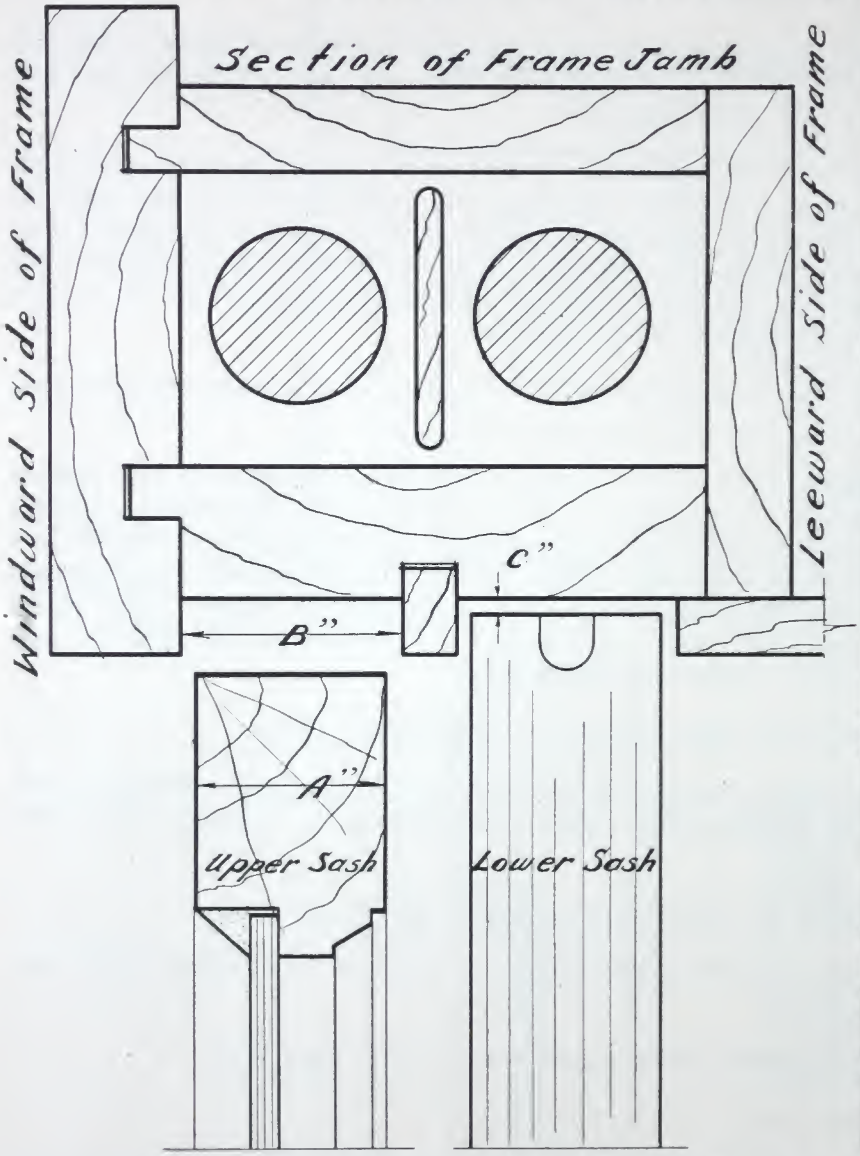
The frame in all cases will have staff beads.

6. **Doors and Frames**—The frame, staff bead and door to main entrance will be of quarter sawn White Oak. All other exterior frames and doors throughout the building will be of soft wood as mentioned, to paint.

All exterior frames unless otherwise specified to be double rabbetted 1¾″ thick.

Sash to these openings to be 1¾″ thick.

SHRINKAGE DIAGRAM DOUBLE HUNG SASH



			A	B	Diff.	C
North Windows	1	N	1.422	1.46	.037	.100
	2	N	1.404	1.46	.056	.105
	3	R	1.407	1.46	.052	.170
	4	R	1.418	1.465	.047	.125
Average			1.413	1.461	.048	.125
East Windows	1	N	1.427	1.474	.047	.110
	2	N	1.417	1.45	.032	.065
	3	N	1.391	1.441	.050	.070
	4	R	1.429	1.45	.021	.085
Average			1.416	1.454	.037	.082
South Windows	1	N	1.406	1.467	.060	.107
	2	N	1.411	1.464	.052	.125
	3	N	1.402	1.46	.058	.087
	4	N	1.403	1.44	.037	.112
Average			1.406	1.457	.052	.108
West Windows	1	N	1.411	1.455	.044	.090
	2	N	1.415	1.45	.035	.130
	3	N	1.412	1.45	.038	.065
	4	N	1.422	1.465	.042	.105
Average			1.415	1.455	.040	.097

	AGE
N = Nelson's House	6 yrs
R - Rose's House	6 yrs

Height overall of Sash	54"
Width of Sash	32 1/4"

INVESTIGATION & REPORT FROM
UNIVERSITY of WISCONSIN
SCHOOL of ENGINEERING (STEAM & GAS DEPT.)
MADE BY D.W. NELSON & R.A. ROSE
APPROVED BY B. SPIETH ASST. PROFESSOR.

Fig. 13.

Knowing the clearance between A and B as shown on page 22, it was necessary to also determine the mean maximum crack C shown on the opposite page.

Twenty leading mechanical schools were asked to measure four windows on each exposure with inside and outside calipers, on their own buildings. This gave sixteen measurements taken by each university and the conditions found are given. The minimum crack was found to be 3/64″ and the minimum clearance 3/64″, with a maximum crack of 17/64″ and a maximum clearance of 9/64″. The average shown by all universities for crack A is 3/16″ and for clearance B is 3/32″. The reports were made on windows from 5 to 15 years old.

It is this crack of 3/16″ and clearance of 3/32″ that more closely approximates the condition of all sash after a period of years. We do not attempt to advise the architect or engineer what crack or clearance should be used in estimating radiation; but the average crack and clearance in any event should be used, as the best condition is that of a new building and infiltration increases with the age of the building and the consequent shrinkage of the sash and frame. As in designing a heating plant for the minimum outside temperature condition, so should the maximum crack and clearance condition be used. The reproduction on the opposite page is an exact copy of a signed report received from the University of Wisconsin and is typical of all received.

CHART ON INFILTRATION OF DOUBLE HUNG (SLIDING) WINDOW

COMPARATIVE LEAKAGES

Double Hung (Sliding) Window 1 3/8" Sash

Leakage C.F.H. per ft. Crack per mile Wind Velocity

B.T.U. Per hour per ft. crack per mile Wind Velocity 70° Temp. Diff.

Non-Stripped window				Monarch #400 Interlocking Weather Strip								Tongue & Groove (Rib Type) Weather Strip							
Crack "A"		1/16" to 1/4"		1/16"		1/8"		3/16"		1/4"		1/16"		1/8"		3/16"		1/4"	
		INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.
Clearance B	1/16	2.1	2.65	.3	.38	.4	.50	.6	.76	.7	.88	1.2	1.51	1.4	1.76	1.7	2.14	2.3	2.90
	3/32	2.9	3.65	.4	.50	.5	.63	.7	.88	.9	1.13	1.3	1.64	1.5	1.89	1.9	2.39	2.4	3.02
	1/8	3.7	4.66	.4	.50	.6	.76	.8	1.01	.9	1.13	1.4	1.76	1.6	2.01	2.0	2.52	2.5	3.15
	3/16	5.0	6.30	.4	.50	.6	.76	.8	1.01	1.0	1.26	1.4	1.76	1.6	2.01	2.0	2.52	2.7	3.40

Note: Plain or Non-stripped window figures are for both sashes locked at meeting rail

If frames are not calked add 1.9 Cu. ft. of air per lineal foot of crack per mile wind Velocity

Frame crack = Height plus width X 2

Add 21 cu. ft. per opening per mile wind Velocity for elsewhere leakage

Sash perimeter = 3 X width plus 2 X Height

Fig. 14.

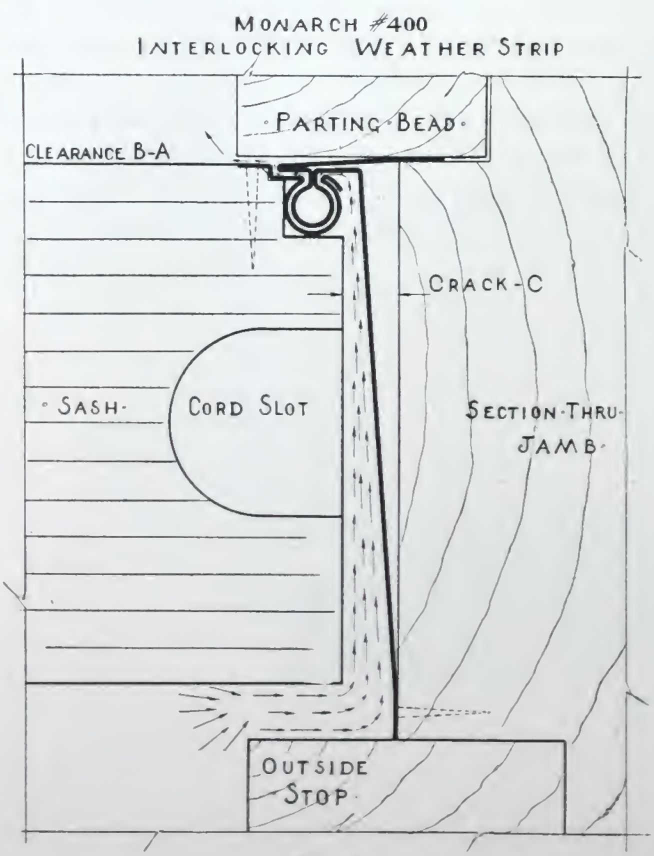


Fig. 15.

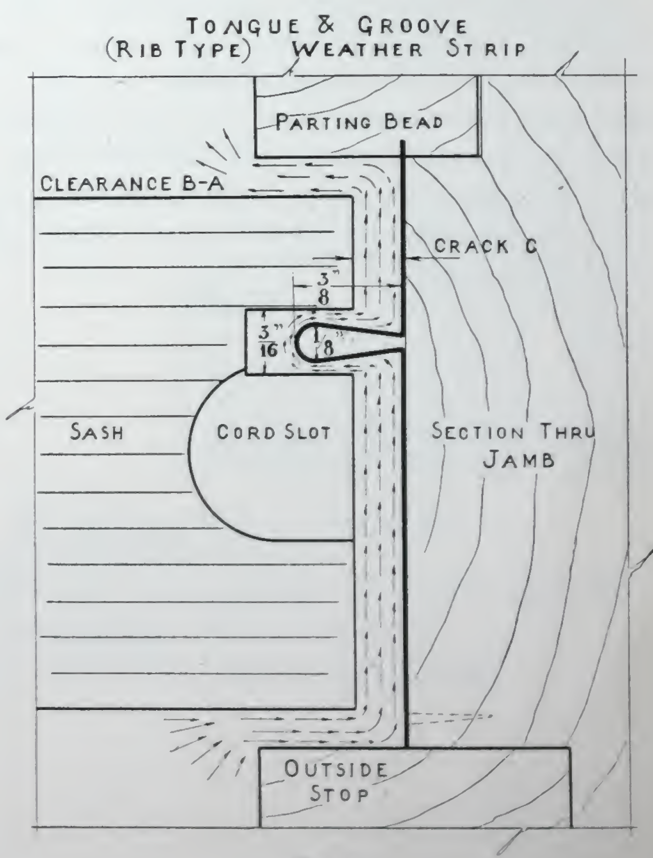


Fig. 16.

LINEAL FEET OF CRACK PERIMETER OF DOUBLE HUNG WINDOWS

To be used in connection with Figure 14 (Page 24).

HGT.	WIDTH										HGT.	WIDTH										HGT.
	2-0	2-2	2-4	2-6	2-8	2-10	3-0	3-2	3-4	3-6		3-8	3-10	4-0	4-2	4-4	4-6	4-8	4-10	5-0	5-2	
4-0	14	14^{6}	15	15^{6}	16	16^{6}	17	17^{6}	18	18^{6}	4-0	19	19^{6}	20	20^{6}	21	21^{6}	22	22^{6}	23	23^{6}	4-0
4-4	14^{8}	15^{2}	15^{8}	16^{2}	16^{8}	17^{2}	17^{8}	18^{2}	18^{8}	19^{2}	4-4	19^{8}	20^{2}	20^{8}	21^{2}	21^{8}	22^{2}	22^{8}	23^{2}	23^{8}	24^{2}	4-4
4-8	15^{4}	15^{10}	16^{4}	16^{10}	17^{4}	17^{10}	18^{4}	18^{10}	19^{4}	19^{10}	4-8	20^{4}	20^{10}	21^{4}	21^{10}	22^{4}	22^{10}	23^{4}	23^{10}	24^{4}	24^{10}	4-8
5-0	16	16^{6}	17	17^{6}	18	18^{6}	19	19^{6}	20	20^{6}	5-0	21	21^{6}	22	22^{6}	23	23^{6}	24	24^{6}	25	25^{6}	5-0
5-4	16^{8}	17^{2}	17^{8}	18^{2}	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	5-4	21^{8}	22^{2}	22^{8}	23^{2}	23^{8}	24^{2}	24^{8}	25^{2}	25^{8}	26^{2}	5-4
5-8	17^{4}	17^{10}	18^{4}	18^{10}	19^{4}	19^{10}	20^{4}	20^{10}	21^{4}	21^{10}	5-8	22^{4}	22^{10}	23^{4}	23^{10}	24^{4}	24^{10}	25^{4}	25^{10}	26^{4}	26^{10}	5-8
6-0	18	18^{6}	19	19^{6}	20	20^{6}	21	21^{6}	22	22^{6}	6-0	23	23^{6}	24	24^{6}	25	25^{6}	26	26^{6}	27	27^{6}	6-0
6-4	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	21^{8}	22^{2}	22^{8}	23^{2}	6-4	23^{8}	24^{2}	24^{8}	25^{2}	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	6-4
6-8	19^{4}	19^{10}	20^{4}	20^{10}	21^{4}	21^{10}	22^{4}	22^{10}	23^{4}	23^{10}	6-8	24^{4}	24^{10}	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	6-8
7-0	20	20^{6}	21	21^{6}	22	22^{6}	23	23^{6}	24	24^{6}	7-0	25	25^{6}	26	26^{6}	27	27^{6}	28	28^{6}	29	29^{6}	7-0
7-4	20^{8}	21^{2}	21^{8}	22^{2}	22^{8}	23^{2}	23^{8}	24^{2}	24^{8}	25^{2}	7-4	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	30^{2}	7-4
7-8	21^{4}	21^{10}	22^{4}	22^{10}	23^{4}	23^{10}	24^{4}	24^{10}	25^{4}	25^{10}	7-8	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	29^{10}	30^{4}	30^{10}	7-8
8-0	22	22^{6}	23	23^{6}	24	24^{6}	25	25^{6}	26	26^{6}	8-0	27	27^{6}	28	28^{6}	29	29^{6}	30	30^{6}	31	31^{6}	8-0
8-4	22^{8}	23^{2}	23^{8}	24^{2}	24^{8}	25^{2}	25^{8}	26^{2}	26^{8}	27^{2}	8-4	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	30^{2}	30^{8}	31^{2}	31^{8}	32^{2}	8-4
8-8	23^{4}	23^{10}	24^{4}	24^{10}	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	8-8	28^{4}	28^{10}	29^{4}	29^{10}	30^{4}	30^{10}	31^{4}	31^{10}	32^{4}	32^{10}	8-8
9-0	24	24^{6}	25	25^{6}	26	26^{6}	27	27^{6}	28	28^{6}	9-0	29	29^{6}	30	30^{6}	31	31^{6}	32	32^{6}	33	33^{6}	9-0
9-4	24^{8}	25^{2}	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	9-4	29^{8}	30^{2}	30^{8}	31^{2}	31^{8}	32^{2}	32^{8}	33^{2}	33^{8}	34^{2}	9-4
9-8	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	29^{10}	9-8	30^{4}	30^{10}	31^{4}	31^{10}	32^{4}	32^{10}	33^{4}	33^{10}	34^{4}	34^{10}	9-8
10-0	26	26^{6}	27	27^{6}	28	28^{6}	29	29^{6}	30	30^{6}	10-0	31	31^{6}	32	32^{6}	33	33^{6}	34	34^{6}	35	35^{6}	10-0
10-4	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	30^{2}	30^{8}	31^{2}	10-4	31^{8}	32^{2}	33	33^{2}	33^{8}	34^{2}	34^{8}	35^{2}	35^{8}	36^{2}	10-4
10-8	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	29^{10}	30^{4}	30^{10}	31^{4}	31^{10}	10-8	32^{4}	32^{10}	33^{4}	33^{10}	34^{4}	34^{10}	35^{4}	35^{10}	36^{4}	36^{10}	10-8
11-0	28	28^{6}	29	29^{6}	30	30^{6}	31	31^{6}	32	32^{6}	11-0	33	33^{6}	34	34^{6}	35	35^{6}	36	36^{6}	37	37^{6}	11-0
11-4	28^{8}	29^{2}	29^{8}	30^{2}	30^{8}	31^{2}	31^{8}	32^{2}	32^{8}	33^{2}	11-4	33^{8}	34^{2}	34^{8}	35^{2}	35^{8}	36^{2}	36^{8}	37^{2}	37^{8}	38^{2}	11-4
11-8	29^{4}	29^{10}	30^{4}	30^{10}	31^{4}	31^{10}	32^{4}	32^{10}	33^{4}	33^{10}	11-8	34^{4}	34^{10}	35^{4}	35^{10}	36^{4}	36^{10}	37^{4}	37^{10}	38^{4}	38^{10}	11-8
12-0	30	30^{6}	31	31^{6}	31	32^{6}	33	33^{6}	34	34^{6}	12-0	35	35^{6}	36	36^{6}	37	37^{6}	38	38^{6}	39	39^{6}	12-0

Fig. 17.

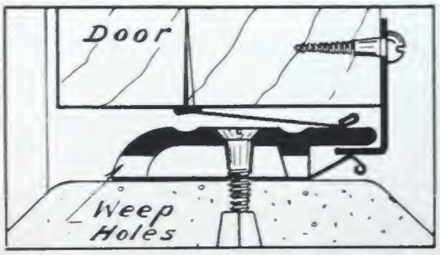
CHART ON INFILTRATION OF DOOR

COMPARATIVE LEAKAGES
Door 1¾" Thick
Leakage C.F.H per ft. Crack per mile of Wind Velocity
B.T.U. per hour per ft. Crack per mile Wind Velocity 70° Temp. Diff.

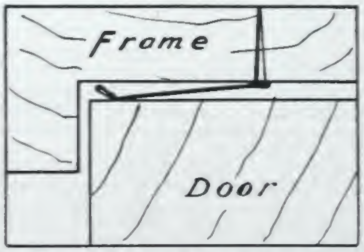
NON STRIPPED DOOR — 1/16" CLEARANCE

Top & Lock Side Cracks	Bottom Crack 1/16"				Bottom Crack 1/8"			
	Hinge Crack 1/16		Hinge Crack 1/8"		Hinge Crack 1/16"		Hinge Crack 1/8"	
	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.	INF.	B.T.U.
1/16"	14.2	17.9	14.9	18.8	19.3	24.3	20.0	25.2
3/32	14.6	18.4	15.5	19.5	19.7	24.8	20.6	26.0
1/8	15.2	19.15	16.3	20.5	20.3	25.6	21.4	27.0
3/16	16.8	21.2	18.3	23.1	21.9	27.6	23.4	29.5
1/4	19.0	23.9	20.9	26.4	24.1	30.4	26.0	32.1

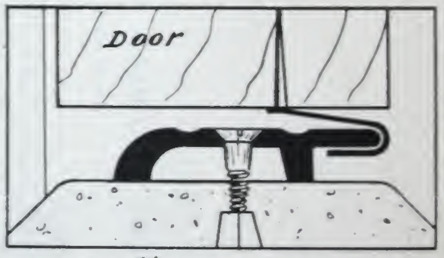
For All Cracks & Clearances	Inf. C.F.H. per ft. Crack per mile Wind Vel.	B.T.U per hour per ft. crack per mile Wind Vel. 70° Temp. Diff.
MONARCH Equip. #800 with #175 Door Bottom	.52	.655
Ordinary Door Bottom Equipment	.63	.80



MONARCH Door Bottom Equipment #175



Detail of Head, Hinge & Lock Side Equip.



Ordinary Door Bottom Equipment

	MONARCH Door Bottom #175	Ordinary Door Bottom
Leakage C.F.H. per ft. of Door Bottom Equip. per mile of Wind Velocity	.70	1.40
B.T.U. per hour per ft. of Door Bottom Equip. per mile of Wind Velocity 70° Temp. Diff.	.88	1.76
Leakage C.F.H. per ft. crack per mile Wind Velocity for Sides & Head only. (Spring Bronze Equip.)	.48	.48

Fig. 18.

DOOR

Consider the leakage through a plain door with special references to the leakage at the bottom of the door. There is nothing at the bottom of a door to give any resistance to infiltration. The air has a free path through the crack. From the table, the infiltration through a door with 1/16" crack all around is 14.2 cu. ft. per hour per foot of crack per mile of wind velocity. With ⅛" crack at the bottom and 1/16" crack on the other three edges, the infiltration is 19.3 cu. ft. Multiplying by the perimeter of the door, we have

14.2x17.6=250 cu. ft.
19.3x17.6=340 cu. ft.

This gives the total leakages per hour per mile for the door in each case, showing a difference of 90 cu. ft. per hour per mile which takes place through approximately 3 feet of crack at the bottom of the door, or 30 cu. ft. per hour per mile per foot of crack. Since this bottom crack is a free opening the leakage will be proportional to the width of the crack or, in other words, an infiltration of 30 cu. ft. per hour per mile will take place through every 1/16" width of crack. In case of a ⅛" crack, the leakage would be 60 cu. ft. per hour per foot of crack per mile of wind velocity.

Subtracting the total leakage through the bottom or 90 cu. ft. per hour in the case of the 1/16" crack, from the total leakage of 250 cu. ft., we get 160 cu. ft through the remaining 14.6 feet of door crack, or $\frac{160}{14.6}=10.95$ cu. ft. per hour per foot of crack, per mile wind velocity.

Sufficient clearance must be allowed at the bottom to allow the door to clear rugs or mats which may be used on floors. In many cases, this clearance is considerably more than ⅛". Therefore, we can see that the leakage through the door depends largely upon the crack at the bottom.

WEATHERSTRIPPED DOOR

The door was tested with two different bottom equipments, in each case having the same equipment at top and sides. The first equipment, Monarch No. 800, gave .52 cu. ft. per hour per foot of crack, per mile wind velocity for the total door, while the second equipment, ordinary door bottom, gave .63 cu. ft. per hour per foot of crack, per mile wind velocity for the total door. Total leakage in each case is as follows:

.52x17.6=9.15
.63x17.6=11.1

This shows a difference of 1.95 cu. ft. per mile through the bottom, since the side and top equipments were identical. This gives $\frac{1.95}{3}=6.5$ cu. ft. per hour per mile wind velocity.

greater leakage through the second equipment.

WIDTH	HEIGHT																		WIDTH
	5'-2	5'-4	5'-6	5'-8	5'-10	6'-0	6'-2	6'-4	6'-6	6'-8	6'-10	7'-0	7'-2	7'-4	7'-6	7'-8	7'-10	8'-0	
1'-0"	12^4	12^8	13	13^4	13^8	14	14^4	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	1'-0"
1'-2"	12^8	13	13^4	13^8	14	14^4	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	1'-2"
1'-4"	13	13^4	13^8	14	14^4	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	1'-4"
1'-6"	13^4	13^8	14	14^4	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	1'-6"
1'-8"	13^8	14	14^4	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	1'-8"
1'-10	14	14^4	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	1'-10
2'-0	14^4	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	2'-0"
2'-2"	14^8	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	2'-2"
2'-4	15	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	2'-4
2'-6"	15^4	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	2'-6"
2'-8"	15^8	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	2'-8"
2'-10	16	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	2'-10
3'-0"	16^4	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	22	3'-0"
3'-2"	16^8	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	22	22^4	3'-2"
3'-4"	17	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	22	22^4	22^8	3'-4"
3'-6"	17^4	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	22	22^4	22^8	23	3'-6"
3'-8"	17^8	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	22	22^4	22^8	23	23^4	3'-8"
3'-10	18	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	22	22^4	22^8	23	23^4	23^8	3'-10
4'-0"	18^4	18^8	19	19^4	19^8	20	20^4	20^8	21	21^4	21^8	22	22^4	22^8	23	23^4	23^8	24	4'-0"

Fig. 19.

LINEAL FEET OF CRACK PERIMETER OF DOORS

To be used in connection with Figure 18 (Page 26).

COMPARATIVE LEAKAGES

Double Inswinging Casement $1\frac{3}{4}$" Sash

Leakage C.F.H. per ft. Crack per mile of Wind Velocity

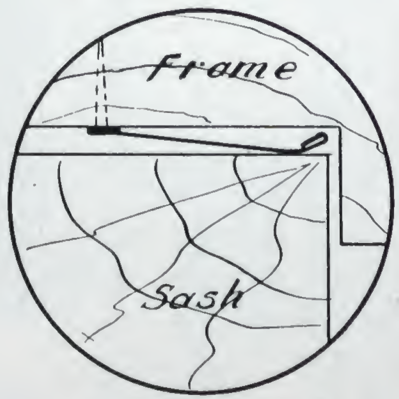
B.T.U. per hour per ft. Crack per mile wind Velocity 70° Temp. Diff.

Top & Bottom Crack	Meeting Rail Crack	Non Stripped Casement		Monarch Equipment #600	
		INFIL.	B.T.U.	INFIL.	B.T.U.
1/16"	1/8"	10.10	12.70	.465	.585
3/32	5/32	11.00	13.85	.475	.598
1/8	3/16	11.65	14.70	.500	.630
3/16	1/4	12.50	15.70	.580	.730
1/4	5/16	13.00	16.35	.690	.870

Crack on hinge Side 1/16" — Clearance 1/16"

Meeting rail Crack 1/8" minimum to permit Closing

Detail of
Sill Equipment



Detail of
Head & Hinge Equip.

Detail of
Meeting Rail Equip.

MONARCH EQUIPMENT #600

Fig. 20.

LINEAL FEET OF CRACK PERIMETER OF DOUBLE CASEMENT WINDOWS

To be used in connection with Figure 20 (Page 28).

WIDTH	HEIGHT																WIDTH	HEIGHT															WIDTH
	3'-0"	3'-2	3'-4	3'-6	3'-8"	3'-10	4'-0"	4'-2	4'-4	4'-6	4'-8	4'-10	5'-0	5'-2	5'-4	5'-6		5'-8	5'-10	6'-0	6'-2	6'-4	6'-6	6'-8	6'-10	7'-0	7'-2	7'-4	7'-6	7'-8	7'-10	8'-0	
2'-0"	13	13^{6}	14	14^{6}	15	15^{6}	16	16^{6}	17	17^{6}	18	18^{6}	19	19^{6}	20	20^{6}	2'-0"	21	21^{6}	22	22^{6}	23	23^{6}	24	24^{6}	25	25^{6}	26	26^{6}	27	27^{6}	28	2'-0"
2'-2	13^{4}	13^{10}	14^{4}	14^{10}	15^{4}	15^{10}	16^{4}	16^{10}	17^{4}	17^{10}	18^{4}	18^{10}	19^{4}	19^{10}	20^{4}	20^{10}	2'-2	21^{4}	21^{10}	22^{4}	22^{10}	23^{4}	23^{10}	24^{4}	24^{10}	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	2'-2"
2'-4	13^{8}	14^{2}	14^{8}	15^{2}	15^{8}	16^{2}	16^{8}	17^{2}	17^{8}	18^{2}	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	2'-4	21^{8}	22^{2}	22^{8}	23^{2}	23^{8}	24^{2}	24^{8}	25^{2}	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	2'-4
2'-6	14	14^{6}	15	15^{6}	16	16^{6}	17	17^{6}	18	18^{6}	19	19^{6}	20	20^{6}	21	21^{6}	2'-6	22	22^{6}	23	23^{6}	24	24^{6}	25	25^{6}	26	26^{6}	27	27^{6}	28	28^{6}	29	2'-6
2'-8	14^{4}	14^{10}	15^{4}	15^{10}	16^{4}	16^{10}	17^{4}	17^{10}	18^{4}	18^{10}	19^{4}	19^{10}	20^{4}	20^{10}	21^{4}	21^{10}	2'-8	22^{4}	22^{10}	23^{4}	23^{10}	24^{4}	24^{10}	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	2'-8
2'-10	14^{8}	15^{2}	15^{8}	16^{2}	16^{8}	17^{2}	17^{8}	18^{2}	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	21^{8}	22^{2}	2'-10	22^{8}	23^{2}	23^{8}	24^{2}	24^{8}	25^{2}	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	2'-10
3'-0	15	15^{6}	16	16^{6}	17	17^{6}	18	18^{6}	19	19^{6}	20	20^{6}	21	21^{6}	22	22^{6}	3'-0	23	23^{6}	24	24^{6}	25	25^{6}	26	26^{6}	27	27^{6}	28	28^{6}	29	29^{6}	30	3'-0
3'-2	15^{4}	15^{10}	16^{4}	16^{10}	17^{4}	17^{10}	18^{4}	18^{10}	19^{4}	19^{10}	20^{4}	20^{10}	21^{4}	21^{10}	22^{4}	22^{10}	3'-2	23^{4}	23^{10}	24^{4}	24^{10}	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	29^{10}	30^{4}	3'-2
3'-4	15^{8}	16^{2}	16^{8}	17^{2}	17^{8}	18^{2}	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	21^{8}	22^{2}	22^{8}	23^{2}	3'-4	23^{8}	24^{2}	24^{8}	25^{2}	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	30^{2}	30^{8}	3'-4
3'-6	16	16^{6}	17	17^{6}	18	18^{6}	19	19^{6}	20	20^{6}	21	21^{6}	22	22^{6}	23	23^{6}	3'-6	24	24^{6}	25	25^{6}	26	26^{6}	27	27^{6}	28	28^{6}	29	29^{6}	30	30^{6}	31	3'-6
3'-8	16^{4}	16^{10}	17^{4}	17^{10}	18^{4}	18^{10}	19^{4}	19^{10}	20^{4}	20^{10}	21^{4}	21^{10}	22^{4}	22^{10}	23^{4}	23^{10}	3'-8	24^{4}	24^{10}	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	29^{10}	30^{4}	30^{10}	31^{4}	3'-8
3'-10	16^{8}	17^{2}	17^{8}	18^{2}	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	21^{8}	22^{2}	22^{8}	23^{2}	23^{8}	24^{2}	3'-10	24^{8}	25^{2}	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	30^{2}	30^{8}	31^{2}	31^{8}	3'-10
4'-0	17	17^{6}	18	18^{6}	19	19^{6}	20	20^{6}	21	21^{6}	22	22^{6}	23	23^{6}	24	24^{6}	4'-0	25	25^{6}	26	26^{6}	27	27^{6}	28	28^{6}	29	29^{6}	30	30^{6}	31	31^{6}	32	4'-0
4'-2	17^{4}	17^{10}	18^{4}	18^{10}	19^{4}	19^{10}	20^{4}	20^{10}	21^{4}	21^{10}	22^{4}	22^{10}	23^{4}	23^{10}	24^{4}	24^{10}	4'-2	25^{4}	25^{10}	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	29^{10}	30^{4}	30^{10}	31^{4}	31^{10}	32^{4}	4'-2
4'-4	17^{8}	18^{2}	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	21^{8}	22^{2}	22^{8}	23^{2}	23^{8}	24^{2}	24^{8}	25^{2}	4'-4	25^{8}	26^{2}	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	30^{2}	30^{8}	31^{2}	31^{8}	32^{2}	32^{8}	4'-4
4'-6	18	18^{6}	19	19^{6}	20	20^{6}	21	21^{6}	22	22^{6}	23	23^{6}	24	24^{6}	25	25^{6}	4'-6	26	26^{6}	27	27^{6}	28	28^{6}	29	29^{6}	30	30^{6}	31	31^{6}	32	32^{6}	33	4'-6
4'-8	18^{4}	18^{10}	19^{4}	19^{10}	20^{4}	20^{10}	21^{4}	21^{10}	22^{4}	22^{10}	23^{4}	23^{10}	24^{4}	24^{10}	25^{4}	25^{10}	4'-8	26^{4}	26^{10}	27^{4}	27^{10}	28^{4}	28^{10}	29^{4}	29^{10}	30^{4}	30^{10}	31^{4}	31^{10}	32^{4}	32^{10}	33^{4}	4'-8
4'-10	18^{8}	19^{2}	19^{8}	20^{2}	20^{8}	21^{2}	21^{8}	22^{2}	22^{8}	23^{2}	23^{8}	24^{2}	24^{8}	25^{2}	25^{8}	26^{2}	4'-10	26^{8}	27^{2}	27^{8}	28^{2}	28^{8}	29^{2}	29^{8}	30^{2}	30^{8}	31^{2}	31^{8}	32^{2}	32^{8}	33^{2}	33^{8}	4'-10
5'-0	19	19^{6}	20	20^{6}	21	21^{6}	22	22^{6}	23	23^{6}	24	24^{6}	25	25^{6}	26	26^{6}	5'-0	27	27^{6}	28	28^{6}	29	29^{6}	30	30^{6}	31	31^{6}	32	32^{6}	33	33^{6}	34	5'-0

Fig. 21.

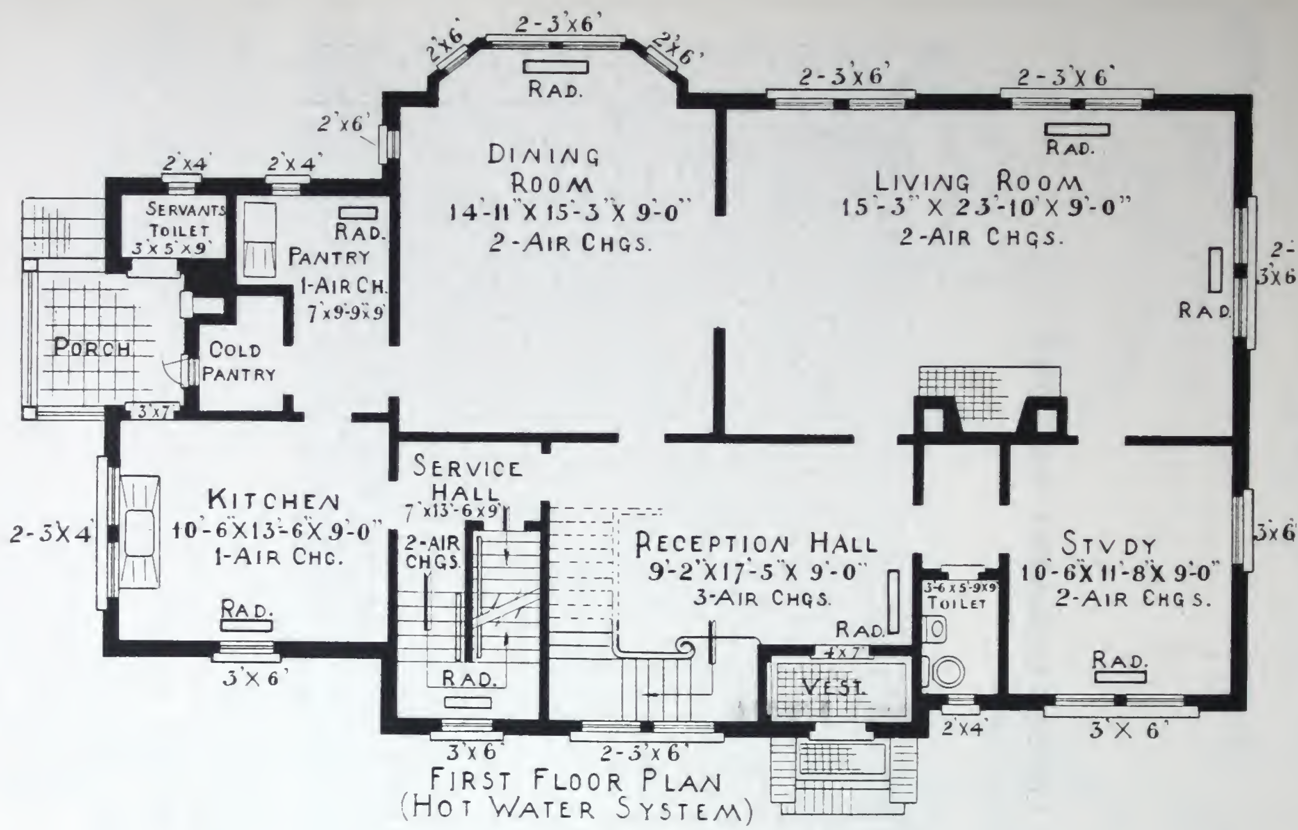


Fig. A

RADIATION COMPARISONS

LIST OF ROOMS	OLD AIR CHANGE METHOD	PIPING CONT'R. CODE	INFIL. THRU WINDOWS: NON STRIPPED	INFIL. THRU WINDOWS: TONGUE & GROOVE (RIB TYPE)	INFIL. THRU WINDOWS: MONARCH #400 INTER'L
STUDY ROOM	17.4	10.3	29.0	21.3	12.8
RECEPTION HALL	34.0	14.4	72.9	16.3	10.4
SERVICE HALL	6.7	8.0	9.7	7.2	4.2
KITCHEN	10.0	12.0	75.3	22.6	14.0
LIVING ROOM	51.4	30.6	52.2	43.2	25.5
DINING ROOM	39.5	23.4	45.3	36.5	20.4
PANTRY	6.4	6.0	7.1	5.6	3.7
TOTAL	165.4	104.7	291.5	152.7	91.0

THE ABOVE RADIATION IS CALCULATED FOR HEAT LOSSES BY AIR CHANGE & INFILTRATION ONLY. TRANSMISSION & EXPOSURE LOSSES WOULD HAVE TO BE ADDED FOR TOTAL RADIATION.

Fig. AA

NOTE—The figures for non-stripped window are based on sash being locked.

Infiltration and B. T. U. Losses are for 1 lineal foot of window crack of various widths and clearances. (See diagram page 24). No allowance is made for the leakage back of the frame, which should be calked. For uncalked frames, add 1.9 cu. ft. per foot of frame crack per hour per mile of wind velocity.

Frame crack equals widths plus height x 2.

Sash crack equals 2 x height plus 3 x width.

Elsewhere leakage is 21 cu. ft. per opening per hour per mile of wind velocity.

NOTE — Size of windows does not affect the elsewhere leakage, as practically all the leakage is through the pulley holes.

Radiation, as laid out, was calculated by five different methods as given in the radiation comparison.

The air change method is what has been commonly used by engineers prior to the investigation made by the Heating and Ventilating Engineers' Society, and are not based on any known facts, but merely assumptions as to the number of times air will change in a room.

Radiation under the Piping Contractors' Code was determined by dividing the cubical contents by 106. This is an arbitrary divisor to simplify computing of radiation. Infiltration figures for radiation are based on known, measured quantities of air that leak in through windows at an average wind velocity of fifteen miles per hour. Temperatures were taken at zero outside to 70° inside.

If the radiation for infiltration is based on a known quantity of air that must be heated to 70°, it is manifestly impossible to heat that same amount of air to 70° with radiation based on either the air change method or the piping contractors' code.

To purchase a tongue and groove or rib type of strip for these two conditions is but added expense of material to get the increase in temperature without saving any cost of installation or reduction in consumption of fuel.

Monarch No. 400 applied to any of the four preceding conditions effects a very material reduction in cost of both radiation and fuel.

EXAMPLES

Conditions

Wind Velocity..15 miles per hour
Outside Temperature............................ 0°
Inside " ....70°
Air Changes per hour........................... 2

All windows calked.

B. T. U. loss per cu. ft. of air per degree differences between inside and outside temperatures, .018. For 70°, .018x70=1.26.

Steam Radiation — Radiator efficiency 240 B. T. U. per square foot.

Radiation in the following examples is for air conditions only. Transmission and exposure losses should be added.

NOTE—Dimensions of rooms differ, cubical content, however, is the same.

Room No. 1

Size—15′x16′x9′
Location—North West Corner
Windows—2 North, 2 West
Size Windows—3′x6′
Total Crack Perimeter—84′
Crack—3/16″, Clearance—3/32″.

Solution

Air Change—15x16x9=2160 cu. ft. Contents.
2 Air Changes—2x2160=4320 Cu. Ft. Contents

$\frac{4320x.018x70}{240}$=22.2 Sq. Ft. Radiation

Non-Strip=$\frac{(84x15x2.9)+(4x21x15)x(.018x70)}{240}$=25.7 Sq. Ft.

T. & G.=$\frac{(84x15x.9)+(4x21x15)x(.018x70)}{240}$=19.11 Sq. Ft.

Mon. No. 400=$\frac{(84x15x.7)+(4x21x15)x(.018x70)}{240}$=11.2 Sq. Ft.

Room No. 2

Size—12′x20′x9′
Location—North Side
Windows—3
Size Windows—4′x5′
Total Crack Perimeter—68′
Crack ⅛″, Clearance ⅛″

Solution

Air Change—12x20x9=2160 Cu. Ft. Contents
2 Air Changes—2x2160=4320 Cu. Ft. Contents

$\frac{4320x.018x76}{240}$=22.2 Sq. Ft. Radiation

Non-Strip=$\frac{(68x15x3.7)+(3x21x15)x(0.18x70)}{240}$=24.6 Sq. Ft.

T. & G.=$\frac{(68x15x1.6)+(3x21x15)x(.018x70)}{240}$=13.5 Sq. Ft.

Mon. No. 400=$\frac{(68x15x.6)+(3x21x15)x(.018x70)}{240}$=8.2 Sq. Ft.

Room No. 3

Size—14'x17'2"x9'
Location—North East
Windows—2 East, 2 North, Double Hung
Size Windows—3'x6' on East, 4'x7' on North
Crack Perimeter—42' on East, 52' on North
Crack—3/16", Clearance 1/16".

Solution

Air Change—14x17'2"x9'=2160 Cu. Ft. Contents
2 Air Changes—2x2160=4320 Cu. Ft. Contents

$$\frac{4320\text{x}.018\text{x}70}{240}=22.2 \text{ Sq. Ft. Radiation}$$

$$\text{Non-Strip—}\frac{(94\text{x}15\text{x}2.1)+(4\text{x}21\text{x}15)\text{x}(.018\text{x}70)}{240}=22.1 \text{ Sq. Ft.}$$

$$\text{T. \& G.—}\frac{(94\text{x}15\text{x}.7)+(4\text{x}21\text{x}15)\text{x}(.018\text{x}70)}{240}=19.21 \text{ Sq. Ft.}$$

$$\text{Mon. No. }\frac{400\text{—}(94\text{x}15\text{x}.6)+(4\text{x}21\text{x}15)\text{x}(.018\text{x}70)}{240}=11.0 \text{ Sq. Ft.}$$

The component parts of each equation are as follows, using the Tongue and Groove equation for room No. 3 as an example: (94x15x1.7)+(4x21x15)x(.018x70)

$$\frac{(A\ \ B\ \ C)+(D\ \ E\ \ B)\text{x}(F\ \ \ G)}{\underset{H}{240}}=R$$

A—Lineal Feet of Crack
B—Wind Movement in miles per hour
C—Infiltration in Cu. Ft. per foot of crack per mile of wind movement.
D—Number of Windows
E—Cubic Feet of Elsewhere leakage through any size window
F—Number of B. T. U. required to raise 1 cu. ft. of air 1° F.
G—Degrees difference in inside and outside temperature (0°—70°)
H—B. T. U. emitted by 1 sq. ft. of direct steam radiation.
R—Radiation

NOTE—If hot water radiation is figured, divide by H=160, or if vapor is used H=200.

COMPARISONS

	Air Change	Non Strip	T. & G. (Rib)	Monarch No. 400
Room No. 1	22.2	25.7	19.11	11.2
Room No. 2	22.2	24.6	13.5	8.2
Room No. 3	22.2	22.1	19.2	11.0

CONCLUSION

A successful heating plant from the standpoint of operation, low installation costs and economy of fuel, must be designed by an engineer using heat loss factors that will remain prectically constant for years after a building has been in use.

No pre-determined number of air changes can possibly remain constant. Wind velocity and direction, size of crack and clearance between sash and frame, the number of windows in a room and the size of the room, all affect the number of air changes. The size of the room and the number of windows are the only factors that remain constant. Therefore, to use any given number of air changes is at best only guess work and not engineering.

Cracks and clearances between sash and frame must remain constant if a known leakage is to be figured. Both Houghten and Schrader in their reports prove conclusively that the efficiency of the tongue and groove (rib type) weather strip, is dependent on the efficiency of the frame and sash; and that the variable in infiltration is the same in the non-stripped window as in the rib stripped window.

By comparison, Monarch Interlocking Tubular Equipment maintains a fixed clearance through which a known volume of air filters; and at the same time, it adjusts itself to any variation in the crack. Therefore, if Monarch Equipment No. 400 is used and radiation is based on the worst condition of the sash, less radiation will be required, and consequently less fuel, than if based on the best conditions of the tongue and groove (rib) type strip.

We invite all who are interested in the contents of this booklet and desire further information, to write us and also to make use of our Laboratory and Engineering Department.

(SPECIFICATIONS)
WEATHER STRIPS

Note—See General conditions which are made a part of these specifications

All windows and doors to be weather stripped for the purpose of keeping out cold air, dust and rain.

This contractor shall examine all windows and doors to be weather stripped to familiarize himself not only with the conditions of the wood-work and parts to which the weather strips are to be attached, but also to ascertain if his standard equipment will fit the detail of the window, but no alterations or changes in the general construction will be permitted except upon written consent of the Architects. The windows and doors shall be removed from their frames and refitted where necessary, so as to properly operate with all hardware attached before any weather strips are applied. After this is done, the windows and doors will be removed from their frames and the weather strips applied as follows:

Materials: Where zinc is used, it shall be not less than No. 9 cut across the grain, secured to sash or frame with barbed flat head tinned nails. Where copper is used it shall not be less than twelve ounce cold rolled, patent leveled secured with copper, bronze or brass barbed flat head nails. Where bronze is used, it shall be not less than 31 B. & S. gage, having a resilliancy equal to, or in excess of, 9 points hard bronze, to contain approximately 90% copper and 10% spelter, to be secured to sash of frame the same as copper strips. Where brass is used, it shall not be lighter than No. 20 B & S gage.

Installation: All vertical weather strips are to be applied in such a manner as to bring all sealing points, or lines of contact, outside of the points or lines of contact of horizontal weather strips coordinating with the vertical strips; for instance, in double hung windows the weather strip on the jamb of the upper sash shall be to the weather side of the line of contact of the meeting rail strip. Vertical strip in jamb of lower sash shall be outside of the sill strip. Casement windows and doors; the vertical weather strip shall have all lines of contact or seals, outside of the line of contact of the sill strip. Double hung and casement windows to be equipped with two membered interlocking strips attached to frame and sash designed to permit swelling and shrinking of sash on frame.

The purpose of this specification is to conduct water to the lowest part of the frame by means of the vertical strips and prevent it from getting into the building by means of the line of contact at the sill.

Efficiency: This contractor shall furnish the manufacturer's guarantee that the weather strip equipment installed under these specifications will maintain a uniform efficiency under all conditions; infiltration thru the weather strip shall not be more than .7 cubic feet of air per hour per foot of crack per mile of wind velocity, when attached to a window having a minimum crack of 3/16" and a minimum clearance of 3/32".

Repairs or Adjustments: Defective material or workmanship shall be replaced or adjusted by this contractor, when necessary, without charge to the owner, for a period of ten years.

Tests: A report from a reputable engineer or organization showing that the type of weather strip equipment to be used has been tested and rated, giving the air leakage, will be accepted for consideration by the architect. In the absence of a report this contractor shall agree to have his equipment tested if ordered, by the architect; all tests to be made by the Research Laboratories of the American Society of Heating and Ventilating Engineers, under the code for determining infiltration prepared by the Structural Service Committee A. I. A.

(SPECIFICATIONS)
CALKING

Calking — All exterior Window and Door Frames shall be sealed with Monarch Elastic Calking Compound.

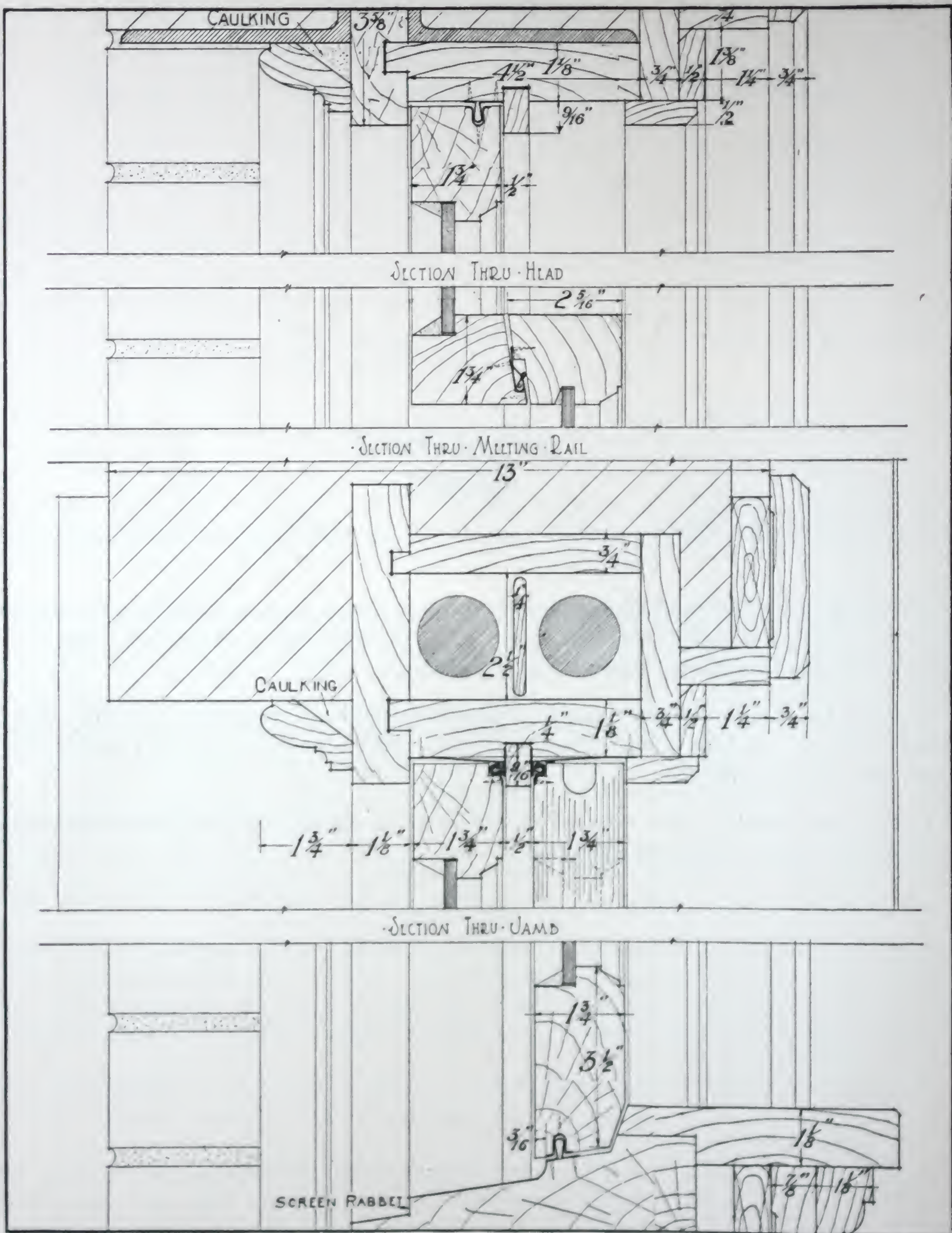
This shall be executed so that the joint between the masonry and frames (heads, jambs and sills) will be rendered weatherproof, wind proof and dust proof, and guaranteed so to remain under all ordinary conditions for a period of 5 years from date of installation.

When spaces between the frames and the surrounding masonry are wider or deeper than ½-inch, these spaces shall be packed within ½-inch of frame surface with oakum and the remaining space filled solid with the calking compound.

The above work shall be done when all frames are set in place and primed and masonry joints raked out, as called for under Masonry Specifications.

MONARCH EQUIPMENT No. 400

SECTION OF DOUBLE-HUNG WINDOW—SHOWING TREATMENT



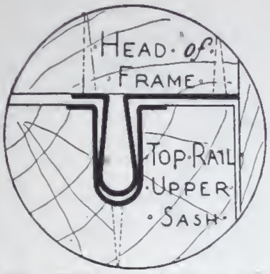
SPECIFICATIONS

Head	Strip #15, on frame	No. 12 zinc cut across grain.
	Strip #13, in sash	No. 9 zinc cut across grain.
	(Same strips and material for Sill treatment)	
Side	Strip #11, on sash	No. 9 zinc cut across grain.
	Strip #1-9, on frame	No. 9 zinc cut across grain.
Meeting Rail	Strip #17, on upper sash	12 oz. cold rolled patent level copper.
	Strip #19, on lower sash	31 gauge spring bronze

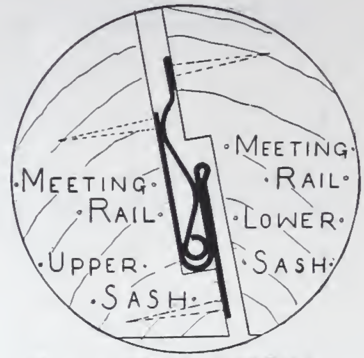
MONARCH EQUIPMENT No. 400

ENLARGED DETAILS—

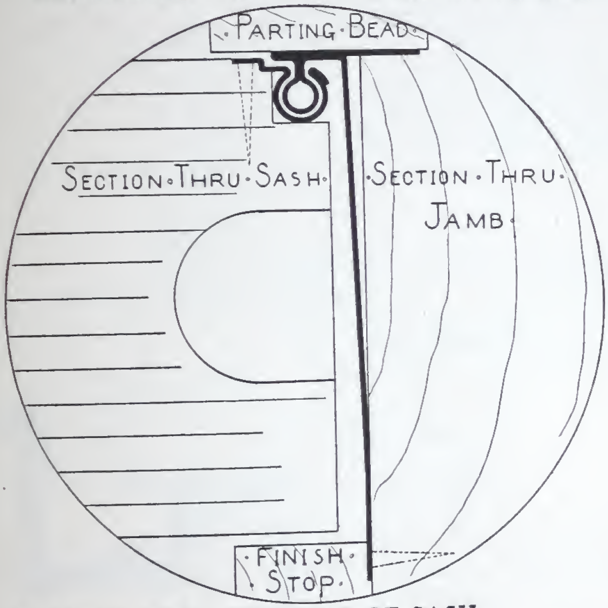
SHOWING MONARCH STRIP APPROXIMATELY 1-1/3 TIMES ACTUAL SIZE



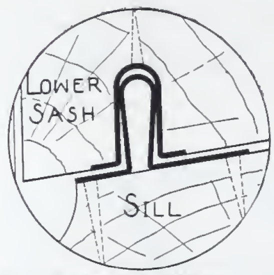
No. 15 STRIP - ZINC - HEAD OF FRAME
No. 13 STRIP - ZINC - TOP RAIL UPPER SASH



No. 17 STRIP - COPPER
MEETING RAIL UPPER SASH
No. 19 STRIP - SPRING BRONZE
MEETING RAIL LOWER SASH



No. 11 STRIP - ZINC - SIDE RAIL OF SASH
No. 1-3-5-7 and 9 STRIPS - ZINC - SECTION THROUGH JAMB
STRIP NUMBER DETERMINED BY THICKNESS OF SASH



No. 13 STRIP - ZINC
BOTTOM RAIL LOWER SASH
No. 15 STRIP - ZINC - SILL

This equipment represents the best result obtained by the Monarch Company in the manufacture of Metal Weather Strips. All demands for prevention of inleakage are met. The free space between the frame and the sash becomes a non-variable machine made crack, no wider than the thickness of a piece of writing paper, or just the necessary space needed to permit sliding of two interlocked members. This is the only space thru which air can enter, and being machine made is not subject to variation when installation is being made.

These interlocked members are attached to the frame on one side, in such a way as to permit lateral movement of the sash, which must be allowed because of seasonal shrinking and warping of the wood.

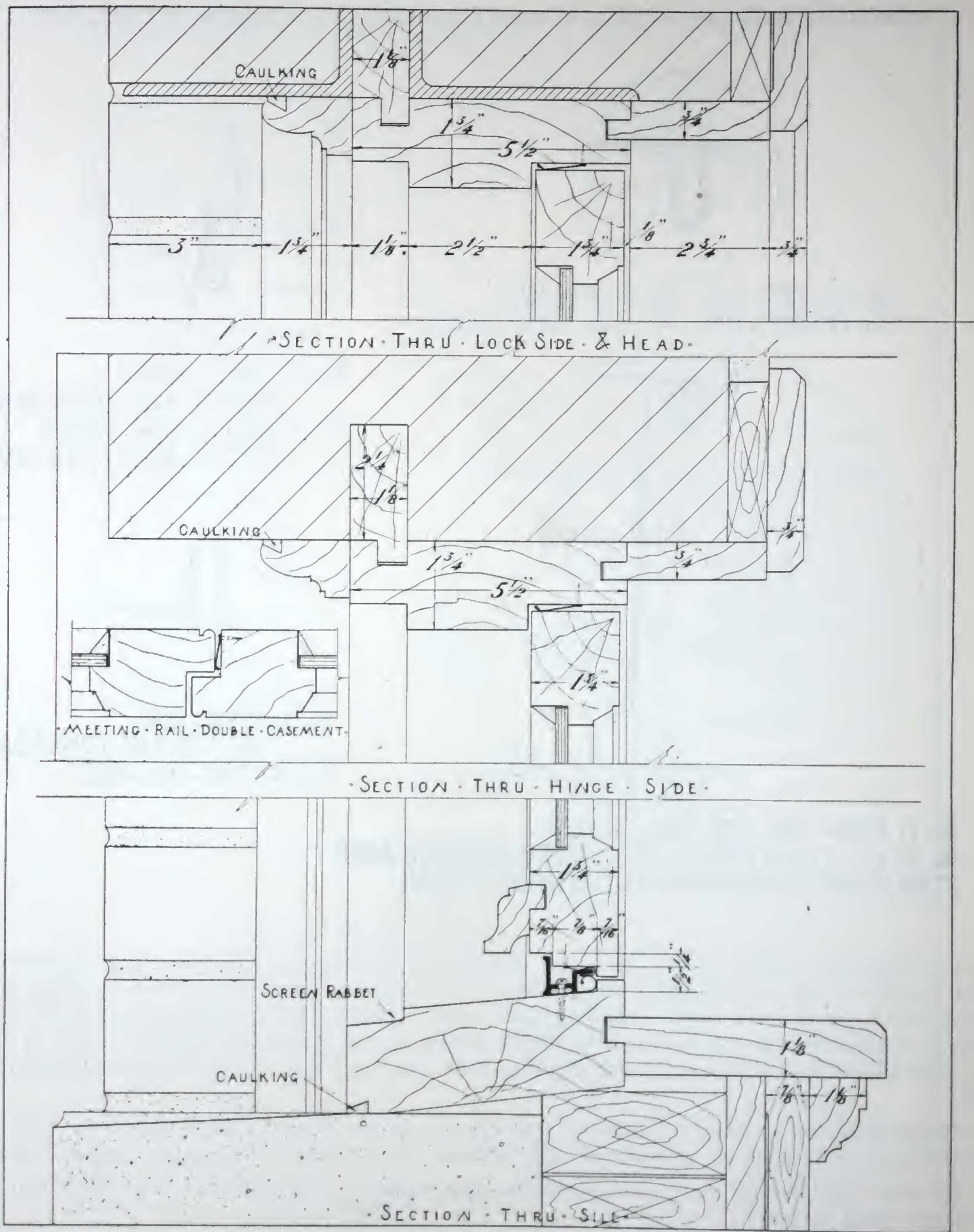
The head and sill treatments give permanent wear, owing to the use of heavy zinc strips that line the grooves at those places.

All sash strips are attached with a flat head, needle point, barbed, metallic tinned nails made of No. 17 steel wire, no less than ⅝″ in length. At the meeting rail, strip No. 17 is nailed on both sides to prevent its coming loose or bending out. Both members at meeting rail are attached with No. 17 flat head, barbed, needle point, brass or copper nails.

NOTE—For information on infiltration through this Equipment No. 400, see Page 24.

MONARCH EQUIPMENT No. 600

SECTION OF CASEMENT WINDOW — SHOWING TREATMENT



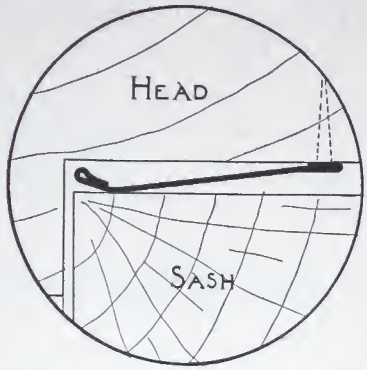
SPECIFICATIONS

Head Lock Side Hinge Side	Strip #57 on Frame	31 Gauge Spring Bronze Double Hemmed
Meeting Rail	Strip #55	31 Gauge Spring Bronze Double Hemmed
Bottom	Strip #145 Female Member Strip #155 Male Member Strip #167 Contact Member	31 Gauge Spring Bronze Extruded Brass 34 Gauge Spring Bronze

MONARCH EQUIPMENT No. 600

ENLARGED DETAILS—

SHOWING MONARCH STRIP APPROXIMATELY 1½ TIMES ACTUAL SIZE



HEAD—LOCK OR HINGE SIDE
No. 57—STRIP—SPRING BRONZE

No. 155—STRIP—EXTRUDED BRASS—SILL
No. 167—STRIP—SPRING BRONZE—SILL
No. 145—STRIP—SPRING BRONZE—SASH

MEETING RAIL—DOUBLE CASEMENT
No. 55—STRIP—SPRING BRONZE—LEFT SASH

In-swinging casements, from every standpoint, present a very difficult problem. They appear to be inevitable water traps, and the principal function of any weather strip equipment for them, should be to baffle the infiltration of water. In so doing, inleakage of air is also prevented.

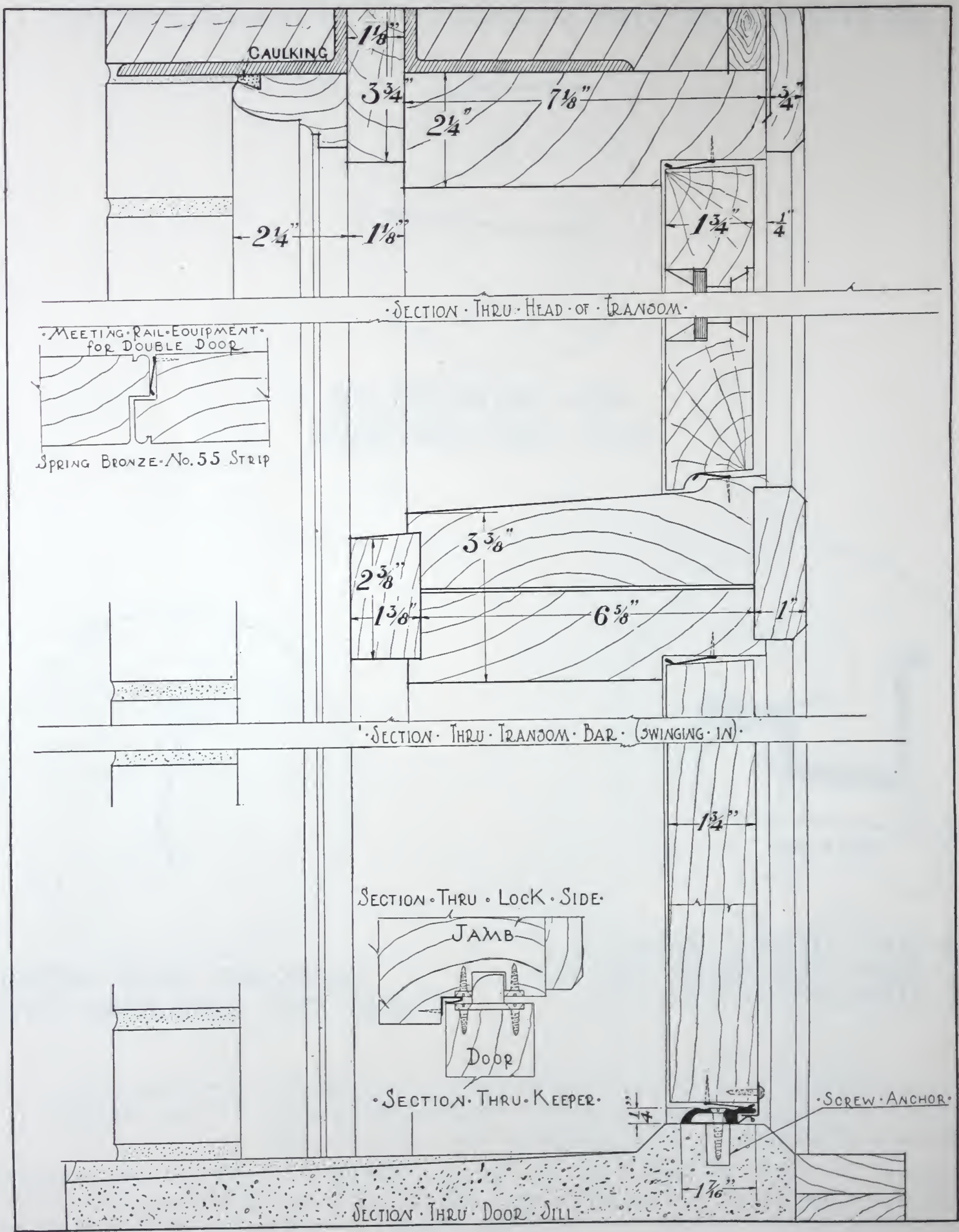
Equipment No. 600 builds up resistance on the three sides and, in double casements, at the meeting rail. Wind driven rain will get past any tongue and hook equipment, as the chief function of this equipment is to reduce the wind pressure. Any water that gets past the tongue will drip down on the sill.

Monarch Strip No. 155, which is a part of Equipment No. 600 successfully overcomes this objection. Water drips off the end of the hook into the flexible trough and is drained out through staggered weep holes under the extruded brass trough. This hook rear trough member also prevents the inleakage of air which might otherwise occur through the weep holes into the interior.

NOTE—For information on infiltration through this Equipment No. 600, see Page 28.

MONARCH EQUIPMENT No. 800

SECTION OF DOOR—SHOWING TREATMENT



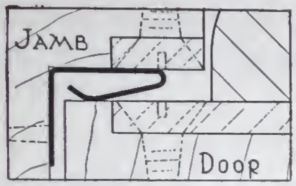
SPECIFICATIONS

Head Lock Side Hinge Side	Strip #57 on Frame		31 Gauge Spring Bronze, Double Hemmed
Keeper	Strip #75 on Frame		31 Gauge Spring Bronze
Bottom	Strip #175	Base Member	Extruded Brass
	Strip #179	Angle Member	20 Gauge Wrought Brass
	Strip # 57	Door Contact Member	31 Gauge Spring Bronze Double Hemmed
	Strip #177	Sill Contact Member	34 Gauge Spring Bronze

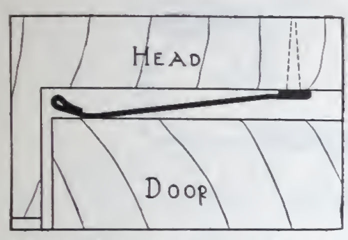
MONARCH EQUIPMENT No. 800

ENLARGED DETAILS —

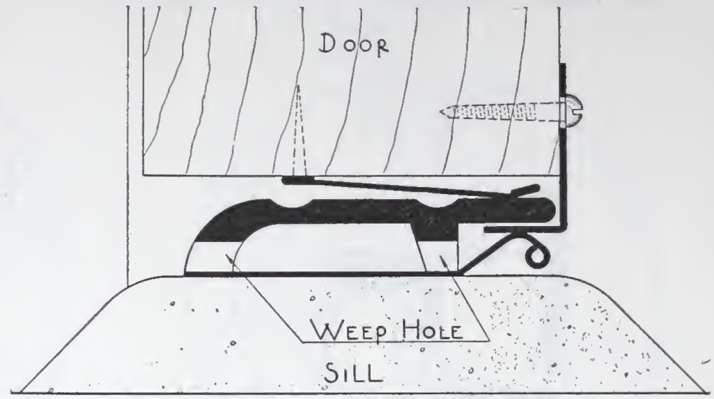
SHOWING MONARCH STRIP APPROXIMATELY 1½ TIMES ACTUAL SIZE



SECTION THRU KEEPER
No. 75—STRIP—SPRING BRONZE



HEAD—LOCK OR HINGE BRONZE
No. 57—STRIP—SPRING BRONZE



No. 175—STRIP—EXTRUDED BRASS—SILL
No. 177—STRIP—SPRING BRONZE—SILL
No. 179—STRIP—BRASS—DOOR
No. 57—STRIP—SPRING BRONZE—DOOR

Doors are by far the most difficult of all openings in buildings to properly weatherstrip. On account of the large amount of wood, swelling and shrinking is extreme and the weight invariably causes sagging.

Equipment No. 800 builds up resistance on the three sides and, in double doors at the meeting rail.

The threshold consists of the extruded brass strip and 2 other members. The line of contact between the door and threshold is made by Spring Bronze No. 57 which shunts the rain to the out-board. In the event that rain does force past this member, secondary resistance is given by a brass angle which cannot be passed and directs the seepage to the weep holes which readily drains to the weatherside because of the natural incline of the sill. The Hook Member No. 177 prevents interior leakage of air through weep holes.

The Monarch Lock Strip No. 75 is also standard for this equipment.

Strip No. 175 is attached to sill by heavy flat head brass screws.

NOTE—For information on infiltration through this Equipment No. 800, see Page 26.

OPTIONAL DOOR SILL EQUIPMENT No. 800-A

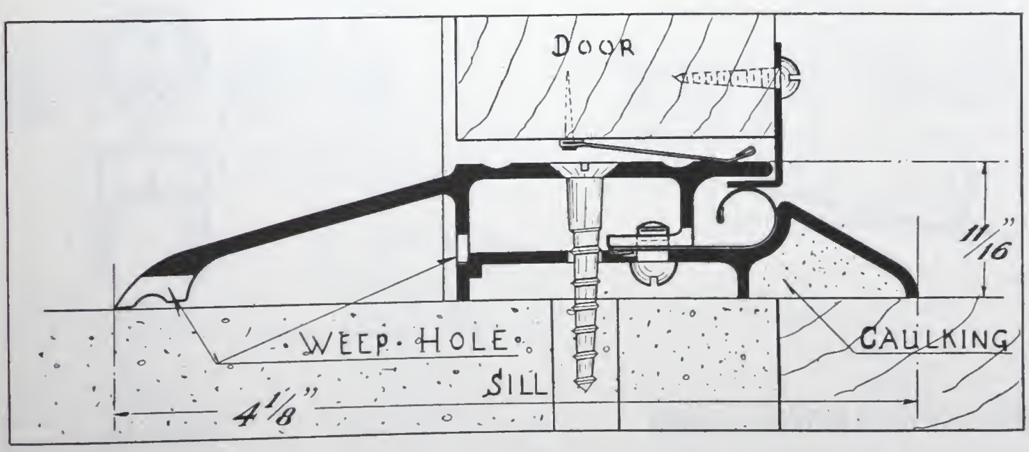


Fig. 23.

DETAIL — ACTUAL SIZE

No. 187—Strip—Extruded Brass—Sill
No. 189—Strip—Extruded Brass—Sill
No. 167—Strip—Spring Bronze —Sill
No. 179—Strip—Brass —Door
No. 57—Strip—Spring Bronze —Door

OPTIONAL SILL EQUIPMENTS

FOR CASEMENTS AND DOORS

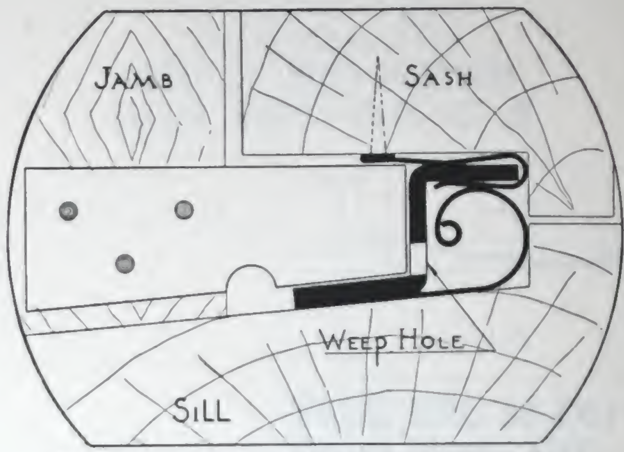
ENLARGED DETAILS—

SHOWING MONARCH STRIP APPROXIMATELY 1½ TIMES ACTUAL SIZE

OPTIONAL CASEMENT SILL EQUIPMENT
No. 600-A

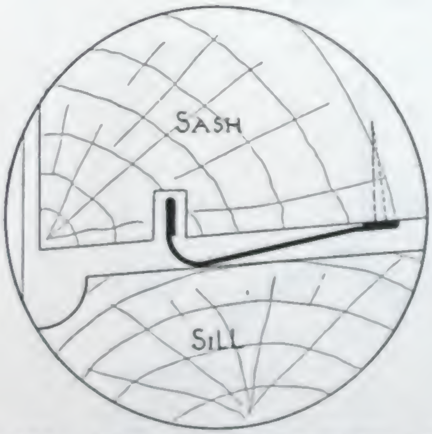
No. 143—STRIP—ROLLED BRASS— SILL
No. 167—STRIP—SPRING BRONZE—SILL
No. 145—STRIP—SPRING BRONZE—SASH

OPTIONAL CASEMENT SILL EQUIPMENT
No. 600-B



No. 159—STRIP—ROLLED BRASS—SILL
No. 167—STRIP—SPRING BRONZE—SILL
No. 145—STRIP—SPRING BRONZE—SASH
No. 161—BAFFLE PLATE—WROUGHT BRASS—JAMB

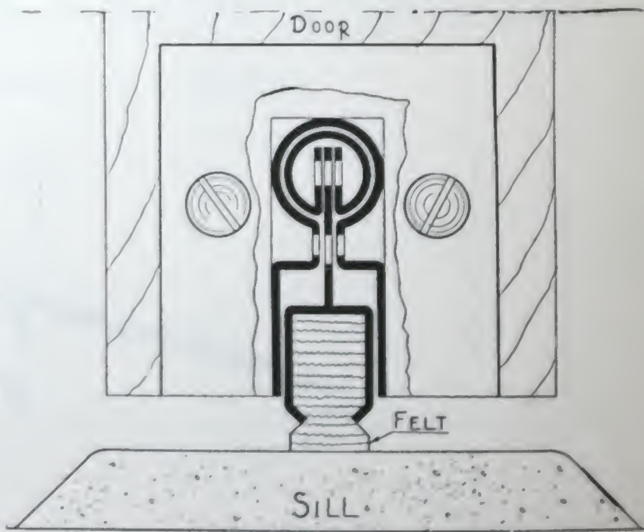
CASEMENT SILL EQUIPMENT



No. 107—STRIP—SPRING BRONZE—SASH

FOR OUTSWINGING CASEMENTS ONLY

OPTIONAL DOOR SILL EQUIPMENT No. 800-B



DOOR SOLE

No. 293—AUTOMATIC DROP BOTTOM

This equipment should never be used where doors are exposed directly to the weather

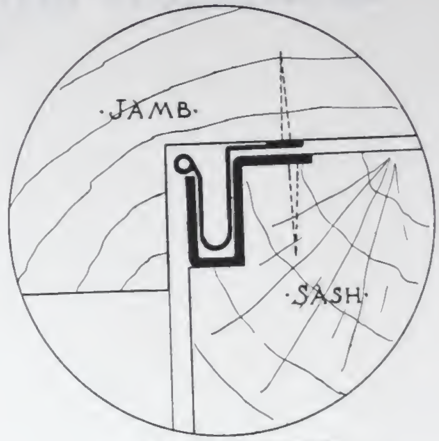
NOTE—All standard and Optional Monarch Weather Strip Equipments shown in this book are guaranteed by the Monarch Company for workmanship and material for a period of ten years from date of installation.

OPTIONAL SIDE, HEAD AND MEETING RAIL EQUIPMENTS

FOR CASEMENTS AND DOORS

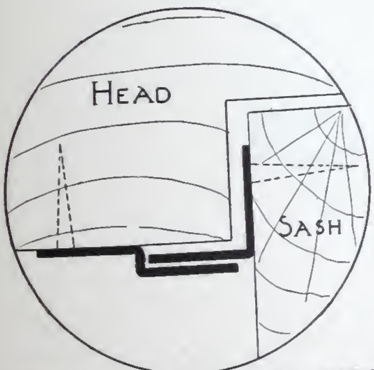
ENLARGED DETAILS—
SHOWING MONARCH STRIP APPROXIMATELY 1½ TIMES ACTUAL SIZE

HEAD OR LOCK SIDE
No. 39—STRIP—SPRING BRONZE—HEAD
No. 47—STRIP—COPPER—SASH

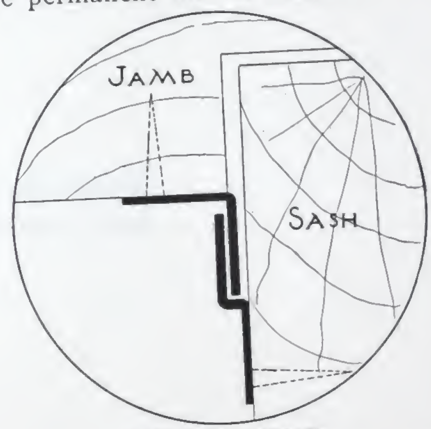


HINGE SIDE
No. 147—STRIP—SPRING BRONZE—JAMB
No. 149—STRIP—BRASS—SASH

In manufacturing the above Interlocking Equipments for casements or doors, head, lock or hinge sides, resilient bronze strips are used in each combination to insure permanent line of contact.

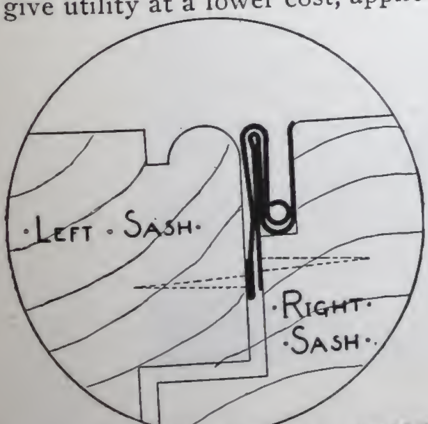


HEAD OR LOCK SIDE
No. 153—STRIP—ZINC OR BRASS—HEAD
No. 151—STRIP—ZINC OR BRASS—SASH



HINGE SIDE
No. 151—STRIP—ZINC OR BRASS—JAMB
No. 153—STRIP—ZINC OR BRASS—SASH

The above Interlocking Equipments for casements or doors, head, lock or hinge side, are designed to give utility at a lower cost, applied to the sash without the need of removing the sash from the frame.



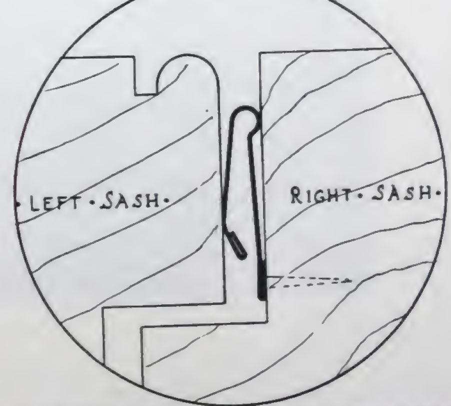
No. 35—STRIP—SPRING BRONZE
MEETING RAIL LEFT SASH
No. 47—STRIP—COPPER
MEETING RAIL RIGHT SASH

OPTIONAL

Meeting Rail Equipments for Double Casements and Doors.

Left Side—Adjustable Interlocking Equipment.

Right Side—No. 133 Strip Cushion Spring Bronze Equipment.



MEETING RAIL—DOUBLE CASEMENT
No. 133—STRIP—SPRING BRONZE—RIGHT SASH

MONARCH METAL PRODUCTS COMPANY

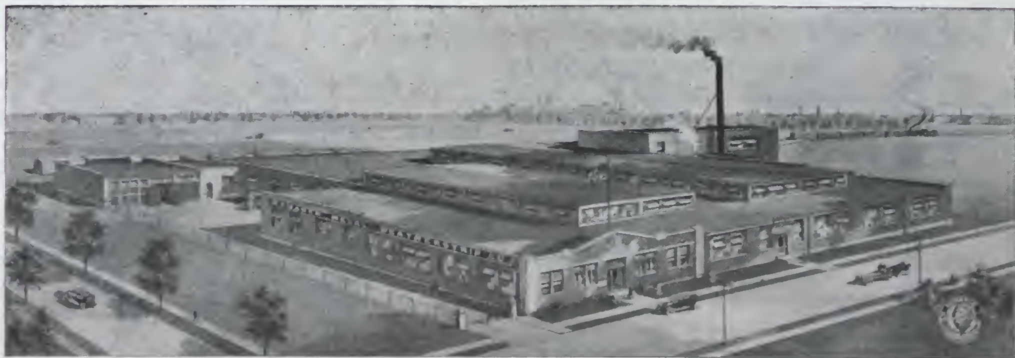
5020 PENROSE STREET

ST. LOUIS, MO.

TRADE MARK

Incorporated 1906

Capital Stock - - - - - - - - - - - -	$180,000
Assets and Resources -- - - - - - - - -	$400,000



Our Plant

MONARCH

METAL PRODUCTS